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# CRASH INJURY EVALUATION

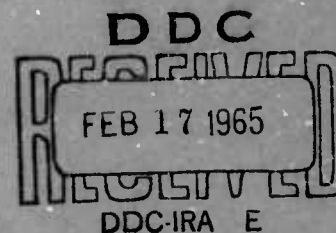
SUMMARY EVALUATION

OF

U. S. ARMY HU - 1A

BELL IROQUOIS HELICOPTER

DECEMBER 1960



AVIATION CRASH INJURY RESEARCH

A DIVISION OF

FLIGHT SAFETY FOUNDATION, Inc.

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TREC Technical Report 60-73

AvCIR 15-PR-126

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TREC Technical Report 60-73  
AvCIR 15-PR-126

SUMMARY EVALUATION  
of  
U. S. ARMY HU-1A BELL HELICOPTER

Based Upon  
Three Evaluations and Five Accidents

For  
United States Army  
Transportation Research Command  
Contract DA-44-177-TC-624

By  
Harold F. Roegner, Chief, Investigation Branch  
and Staff

AVIATION CRASH INJURY RESEARCH  
A Division of  
Flight Safety Foundation, Inc.

30 December 1960



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## FOREWORD

Under a contract with the U. S. Army Transportation Research Command, the Flight Safety Foundation is required to make crash injury reports of selected survivable aircraft accidents and conduct crashworthiness evaluations of model specifications, proposed manufacturer's designs, mock-up's, and current Army aircraft.

In fulfilling this obligation, Aviation Crash Injury Research (AvCIR), a division of the Flight Safety Foundation, is guided by certain criteria which it considers fundamental for the crash protection of aircraft occupants. Following is a brief description of these criteria:

1. Crashworthiness: The ability of basic aircraft structure to provide protection to occupants during survivable impact conditions;
2. Tie-down chain: All components of the occupant seating and restraint system including the seat belt, the shoulder harness, the seat structure, the floor, and related anchorages;
3. Occupant environment: The injury potential of all objects and structure within the occupant's striking range;
4. Transmission of crash force: The manner in which crash forces are transmitted (magnified or attenuated) to the occupants by intervening structure; and
5. Post-crash factors: Post-crash fire, emergency exits, ditching characteristics, etc.

A more complete discussion of crash safety criteria is given in Appendix A.

## BACKGROUND

Since 1955, information on the crash safety features of the HU-1A Bell Iroquois helicopter has been gathered by Aviation Crash Injury Research (AvCIR), formerly affiliated with Cornell University and now a division of Flight Safety Foundation. This encompassed two evaluations by AvCIR, one evaluation by the U. S. Army Board for Aviation Accident Research (USABAAR) and investigation of five major accidents in which this aircraft has been involved where crash forces and injuries have been present.

The first evaluation was conducted on an XH-40 mock-up by AvCIR on 15-16 November 1955 at Fort Worth, Texas. This was done under an Office of Naval Research contract, Nonr-401 (21).

A second evaluation was conducted by USABAAR in conjunction with the U. S. Army Aviation Board, the U. S. Army Transportation Aircraft Test and Support Activity, and the Aviation School's Flight Surgeon's Office on 4-5 November 1958 at Fort Rucker, Alabama. Two YH-40 helicopters were inspected and evaluated; one was flyable, the other had been wrecked while undergoing tests.

The third evaluation was conducted on an HU-1A production model by AvCIR on 22 January 1960 at Fort Rucker, Alabama.

Information resulting from accidents was gathered through three on-the-scene field accident investigations by AvCIR staff:

1. 21 October 1959, East St. Louis, Illinois;
2. 9 June 1960, Fort Carson, Colorado; and
3. 20 August 1960, Fort Bragg, North Carolina.

For two additional accidents at Fort Rucker, Alabama - 3 March 1960 and 26 August 1960 - U. S. Army accident reports were available.\* Summary details for each accident together with charts showing seat failures and occupant injuries are given in Appendix B.

---

\* Accident references throughout the report will be: Accident "A" - East St. Louis; Accident "B" - Fort Rucker, (March 1960); Accident "C" - Fort Carson; Accident "D" - Fort Bragg; and Accident "E" - Fort Rucker (August 1960).

This report reviews and discusses findings, conclusions, and recommendations forthcoming from the three evaluations and the five accident investigations. The purpose of the evaluations and investigations is to:

1. Evaluate the over-all crashworthiness of the basic aircraft structure;
2. Draw attention to all features which could either lead to or prevent unnecessary exposure of crew members and passengers to serious or fatal injury in accidents where crash forces are within survivable limits;
3. Make recommendations for remedial action in areas where deficiencies exist or are believed to exist in order to improve the crash safety aspects of the aircraft; and
4. Note the existence of effective crash safety features.



## SUMMARY

The initial evaluation of the HU-1A Bell helicopter, on an XH-40 mock-up in 1955, cited a number of deficiencies which should be corrected to prevent or minimize injuries in the event of a crash under survivable conditions. These included items such as:

1. Litter installations and adjacent tie-down structure;
2. Troop seats and accompanying seat belt installation;
3. Crew seats;
4. Crew chief or medical attendant seat installation;
5. Emergency evacuation; and
6. Major components - transmission and engine mountings.

Many of these same findings were brought out in the USABAAR evaluation of a test model, YH-40, in 1958; other similar recommendations also were made.

The investigations of three accidents by AvCIR at East St. Louis, Illinois, Fort Carson, Colorado, and Fort Bragg, North Carolina, and two accidents by the U. S. Army at Fort Rucker, Alabama, support a number of the initial evaluation comments regarding possible deficiencies. For example:

1. The tie-down of the transmission failed in all five accidents and, in one case, the transmission did go through the firewall bulkhead into the cabin area;
2. Failure occurred in 80 percent of the occupied troop seats; and
3. Crew seats generally failed because both seat belts and shoulder harness were attached to the seat thus placing full strain entirely on the seat tie-down.

No accident experience was available on litter installations. In addition to these three deficiencies, accident experience brought out the lack of adequate structural integrity in the side vertical supports and in the aft roof supports. It did, however, indicate several features advantageous to crash safety:

1. The skid-type landing gear utilized on the HU-1A absorbs a considerable amount of energy during an accident;
2. The seat cushions currently being used in the crew members' seats also absorb a considerable amount of energy; and
3. The location of the fuel tanks, aft of the passenger compartment and on the sides of the aircraft, is an improvement over those which are located in the belly of most helicopters.

The HU-1A Bell Iroquois helicopter appears to be an excellent aircraft for the purposes to which it is being put by the U. S. Army. However, for increased and practical crash safety, attention to several features is indicated.

1. Tie-down strength of crew seats should be increased;
2. Seat belts and shoulder harness of crew members should be anchored to primary structure;
3. Troop seats should be redesigned to increase occupant protection and seat belts should be fastened to the cables provided rather than to "O" rings;
4. Litter installations should be redesigned for increased occupant protection;
5. Anchorage of both the transmission and the engine should be strengthened; and
6. Priority should be given to the strengthening of the vertical side supports on the HU-1A. (An increase in the gauge thickness of the skin, as suggested by Bell, already has been incorporated into the HU-1B; the alternate of a roll-bar should be considered as a retrofit program for the HU-1A, if at all possible.)

## REFERENCES

Information from the following evaluations, accident investigations, and AvCIR reports was utilized in the preparation of this report.

### EVALUATIONS:

1. XH-40 mock-up evaluation conducted by AvCIR on 15-16 November 1955 at Fort Worth, Texas;
2. YH-40 evaluation conducted by USABAAR in conjunction with the U. S. Army Aviation Board, the U. S. Army Transportation Aircraft Test and Support Activity, and the Aviation School's Flight Surgeon's Office on 4-5 November 1958 at Fort Rucker, Alabama; and
3. HU-1A production model evaluation conducted by AvCIR on 22 January 1960 at Fort Rucker, Alabama.

### ACCIDENT INVESTIGATIONS:

1. 21 October 1959, East St. Louis, Illinois (CRD-2859, AvCIR 10-PR-110);
2. 3 March 1960, Fort Rucker, Alabama;
3. 9 June 1960, Fort Carson, Colorado (TREC 60-72, AvCIR 12-PR-122);
4. 20 August 1960, Fort Bragg, North Carolina (TREC 60-71, AvCIR 13-PR-123); and
5. 26 August 1960, Fort Rucker, Alabama.

### RELATED REPORTS:

1. AvCIR Crash Injury Evaluation, U. S. Army AC-1 DeHavilland Caribou, TREC Technical Report 60-62, AvCIR 14-PV-121, October 1960; and
2. AvCIR Crash Injury Bulletin, Part I Attachment of Seat Belts in the HU-1A Helicopter, Part II Stowage of Equipment Under Troop Seats, TREC Technical Report 60-61, AvCIR 69-O-120, November 1960.



Figure 1. Side View of an HU-1A in Flight

## DESCRIPTION OF AIRCRAFT

The HU-1A Bell Iroquois helicopter is a utility-type aircraft of compact design featuring a low-silhouette and low vulnerability to meet combat requirements. A wide cabin permits the helicopters to be used for transport of personnel, equipment and supplies, for medical evacuation and emergency ambulance service where facilities for fixed-wing aircraft are not available, and as an instrument trainer.

This helicopter is capable of operating from prepared or unprepared take-off or landing areas and under instrument (IFR) conditions.

Maximum visibility is afforded the pilot and crew by extensive use of transparent plastic panels at the top, front, bottom, and sides of the cabin. Crew entrance is accomplished through two swing-hinged doors located in the forward cabin areas next to the pilot's and copilot's station. Entrance to the passenger cargo area is effected by means of two large sliding doors, one on either side of the aft cabin area.

The passenger cargo cabin area contains 2 two-man troop seats that can be folded and stowed against the aft cabin bulkhead. When the seat is folded the area presents an unrestricted loading space for cargo or equipment transportation. For ambulance or mercy mission service a litter rack and medical attendant seat are quickly installed and two litter patients can be carried within the cabin.

The propulsion system is located aft of the cabin and is mounted on a platform above the fuselage.

The fuselage consists of two main sections, the forward section and the aft section or tail boom. The construction of the forward section consists primarily of two longitudinal beams with transverse bulkheads and metal covering. The beams provide the supporting structure for the cockpit cabin section, landing gear, fuel tanks, transmission, engine, tail boom, and the attaching points for the external cargo suspension unit. The tail boom is a semi-monocoque structure with metal covering and is attached to the forward section with bolts to allow easy removal. The rear of the tail boom supports the tail rotor, vertical fin, and synchronized elevator.

The landing gear is of the skid type, attached to the fuselage at four points. Ground handling wheels are provided.

A normal operating crew may consist of a pilot alone, a pilot and a medical attendant, or a pilot and a copilot, depending on the mission assigned.

## ACCIDENT EXPERIENCE

Since introduction of the HU-1A helicopter into U. S. Army operation, there have been a total of five accidents where crash forces were sufficient to destroy the aircraft and cause injury to all occupants. These five accidents are described briefly in Appendix B; a chart showing seating arrangement, seat failure, and occupant injuries accompanies each description. These are in addition to the accident involving the test model YH-40 at Fort Rucker, Alabama, which supported the evaluation by USABAAR.

Although the impact conditions in these accidents varied, they all were well within known survivable limits (see Table 1). However, there was considerable buckling, distortion, or collapse to top, bottom, and sides of the occupiable area (see Table 3) and substantial damage to major components, particularly the transmission (see Table 4).

Fifteen persons were involved: Five pilots, four persons (passenger or crew chief) occupying the copilot's seat, one crew chief, and five passengers. All sustained injuries ranging from Minor (abrasions, lacerations, or contusions) to Critical (brain concussion and depressed fracture of the base of the skull). The latter injury was caused by a portion of the aft firewall which struck the occupant of the troop seat. (See Appendixes B and D for complete details of all injuries and Appendix C for AvCIR Scale of Injuries; see Table 2 for summary.)

All seat belts remained intact as did all shoulder harnesses. (There was no shoulder harness installation in Accident "A".) This probably contributed to the seat failures in the crew compartment since both seat belt and shoulder harness are fastened to the seat rather than to primary structure. Where occupied, troop seats generally collapsed, tore free, or were distorted (see Table 5).

The accident experience and the effects from a crash injury point of view are discussed fully under major categories in the sections to follow.

TABLE 1  
IMPACT CONDITIONS\*

Accident Designation	Obstacle Collision	Principal Impact	Fwd. Vel. (Knots)	Rate of Descent	Flight Path Angle	Pitch	Roll	Yaw
A	None	Soft Ground	40-50	1600-2000 FPM	20°	Level	Level	None
B	Trees	Soft Ground	35	1300 FPM	20°	15° Up	15° Right	15° Right
C	Trees	Rocky Ground	25	1500 FPM	45°	45° Up	Level	None
D	Trees	Tree Stump Soft Ground	9	1500 FPM	60°	15° Up	Level	30° Left
E	Trees	Soft Ground	0	1000 FPM	90°	Level	75° Left	30° Left

\* All figures approximate.

TABLE 2  
DEGREE OF INJURY TO OCCUPANTS

Accident Designation	Number of Occupants	Degree of Injury AvCIR Scale
A	2	Pilot - Serious Crew Chief (copilot's seat) - Minor
B	1	Pilot - Severe
C	4	Pilot - Minor; Passenger (copilot's seat) - Moderate Seat L-1 - Moderate; Seat R-1 - Minor
D	6	Pilot - Serious Passenger (copilot's seat) - Serious Crew Chief - Severe; Seat L-1 - Minor Seat R-1 - Critical; Seat R-2 - Serious
E	2	Pilot - Minor Crew Chief (copilot's seat) - Minor
Total	15	1 - Critical 4 - Serious 2 - Severe 2 - Moderate 6 - Minor

TABLE 3  
DAMAGE TO OCCUPIABLE AREA

Accident Designation	Nose	Top	Bottom	Left Side	Right Side	Rear Bulkhead
A	Partly Collapsed	Collapsed	Distorted	Collapsed	Collapsed	Buckled
B	Partly Collapsed	Partly Collapsed	Distorted	Distorted	Partly Collapsed	Buckled
C	Intact	Distorted	Distorted	Partly Collapsed	Partly Collapsed	Displaced Fwd. 14"
D	Partly Collapsed	Partly Collapsed	Partly Collapsed	Collapsed	Collapsed	Partly collapsed, displaced Fwd. 12"
E	Distorted	Distorted	Intact	Partly Collapsed	Intact	Distorted

TABLE 4  
DAMAGE TO MAJOR COMPONENTS

Accident Designation	Transmission	Engine	Rotor System	Landing Gear	Tail Boom
A	Torn free to the left	Torn free	Torn free with transmission	One cross-tube failed, the other bent & buckled	Torn free
B	Torn free	Partly torn free, displaced right	Torn free	Torn free	Broken & Partially torn free
C	Displaced Fwd. 17"	Intact	Mast distorted, blades broken	Skids buckled, cross-tubes distorted	Buckled
D	Torn free to the right	Intact	Torn free with the transmission	Skids bent, rear cross-tubes failed, front bent	Torn free
E	Displaced right	Unknown	Mast distorted, blades damaged	Skids bent, cross-tubes distorted	Broken



TABLE 5  
DAMAGE TO SEATS, SEAT BELTS, AND SHOULDER HARNESSSES

Accident Designation	Left Front	Right Front	Center	Left Rear	Right Rear	Seat Belts	Shoulder Harness
A	Slightly distorted	Seat pan & seat back distorted. Tie-down intact	Not occupied	Not occupied	Not occupied	All intact	None installed
B	Not occupied	Seat pan distorted. Seat back distorted. Supports broken. Anchorage torn free.	None	Not occupied	Not occupied	All intact	Intact
C	Intact	Intact	None	Intact support & anchorages distorted	Seat pan collapsed. Back torn free. Supports collapsed. Anchorages distorted	All intact	Both front seats intact. Rear seat none
D	Partly torn free. Seat pan distorted. Supports broken. Rear anchorage torn free	Torn free. Seat pan distorted. Seat back buckled. Supports broken	Seat torn free at seat pan. Seat supports collapsed. Anchorages intact. Seat pan broken.	Seat pan partly torn free. Supports pulled out of clamps	Seat pan partly torn. Supports distorted. One support pulled out of clamp. Seat back torn free.	All intact	Both front seats intact. Outer and rear seats none
E	Intact	Torn free	None	Auxiliary fuel tank at this location, which ruptured and partially spilled its contents		All intact	Both intact

EVALUATION OF BASIC AIRFRAMEGENERAL DISCUSSION

During analysis of this aircraft in both evaluations and accident investigations, it was found that a number of desirable crashworthy items are incorporated into the aircraft:

1. The skid-type landing gear incorporates energy absorption capabilities;
2. The location of the fuel tanks offers protection against post-crash fire; and
3. The exits in the aircraft are adequate for post-crash evacuation.

The skid-type landing gear consists of two lateral mounted arched cross-tubes attached to two formed longitudinal skid tubes. The gear assembly is attached, with clamps, at four points of the fuselage structure. The two cross-tubes act as energy absorbers. The location of the cross-tubes and the inner action effects peculiar to this gear provide a nearly equal distribution of landing loads between the cross-tubes for all level attitudes. The favorable energy absorption capabilities of this gear have been demonstrated in at least four of the five accidents. It also was cited as a desirable objective in the initial AvCIR evaluation of the XH-40.

The fuel system utilized in the HU-1A consists of two inter-connected rubber fuel cells. The normally installed tanks are located just aft of the cabin area, one on the left and the other on the right. From a crash injury viewpoint the present installation is far superior to that where the fuel tanks are in the belly. The side-mount tanks are situated in a position which prevents rupturing due to the collapse of the aft lateral skid support. It also should be noted that the engine exhaust is not in a position to ignite the fuel in the event of spillage. This frequently occurs with reciprocating engines due to the downward reflection of the exhaust system. To date no post-crash fires have occurred in HU-1A accidents.

The pilot's and copilot's entrance doors are jettisonable to provide emergency exits. The jettison handles are cradled by brackets attached to the forward post of the doors. Pulling the handles operates a cam to pull the hinge pins and depress the door latches to allow the doors to be released from the helicopter. The main cabin doors are not jettisonable; however, should they become jammed or inoperable the large windows could be broken out to provide an adequate escape route. At the present time there

## SECTION I

are no operating instructions on the exterior of the cabin doors to assist untrained rescue personnel in regard to the operation of these doors. It is suggested that clear readable operating instructions should be placed on the exterior near the operating handles.

Additional markings should be added to the exterior of the aircraft in regard to the location of the hand fire extinguisher for the benefit of untrained rescue personnel.

### COCKPIT/CABIN FUSELAGE

The extreme forward portion of the roof structure of this aircraft is supported by the front door frames and the center strip of the windshield frame structure. The main support is provided by left and right vertical support members shown in Figure 2. The aft end of the roof is supported on a secondary type of structure, the aft firewall bulkhead, also shown in Figure 2.

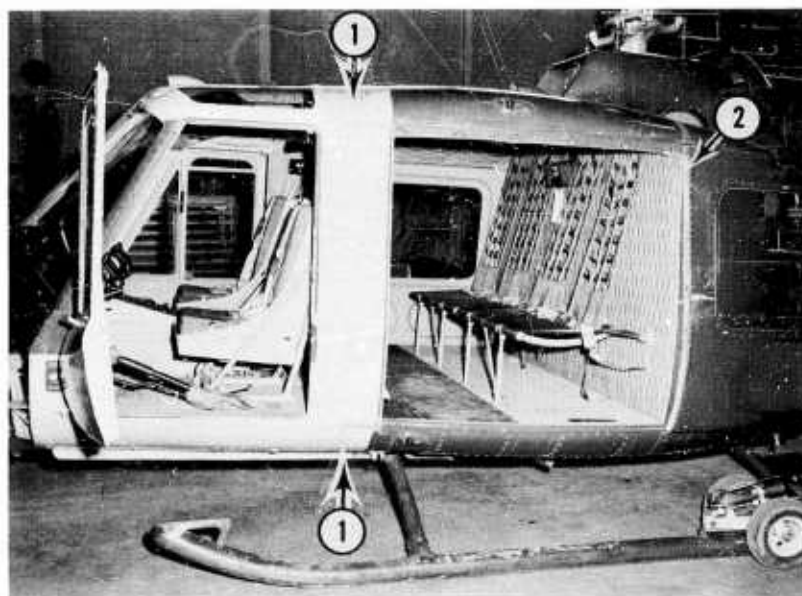


Figure 2. View of the vertical side supports. Arrow 1 denotes the vertical side support; arrow 2 depicts the aft firewall roof support.

## SECTION I

The lower attachment points of the vertical support members on the right and left side of the cabin consists primarily of two "L" stringers, one fore and one aft. The outer skin of this support extends into the roof structure and is attached to the longitudinal roof support. At the present time, according to the Military Specification, this vertical support is required to carry only a normal air load.

Failure of these main side supports plus the failure of the aft bulk-head support permits the roof structure to lower sufficiently to strike the occupants or the seat backs in the occupiable crew and cabin areas. This is clearly demonstrated by the accident experience where the side vertical supports failed in every one of the five accidents, ranging from partial failure in Accident "C" and Accident "E" to complete failure in Accidents "A" and "D" (Figures 3 through 18). The aft end of the roof also failed in all but one of the five accidents (Figures 19 through 24). Only the absence of forward deceleration probably precluded any forward movement of the aft roof supporting structure in Accident "E".

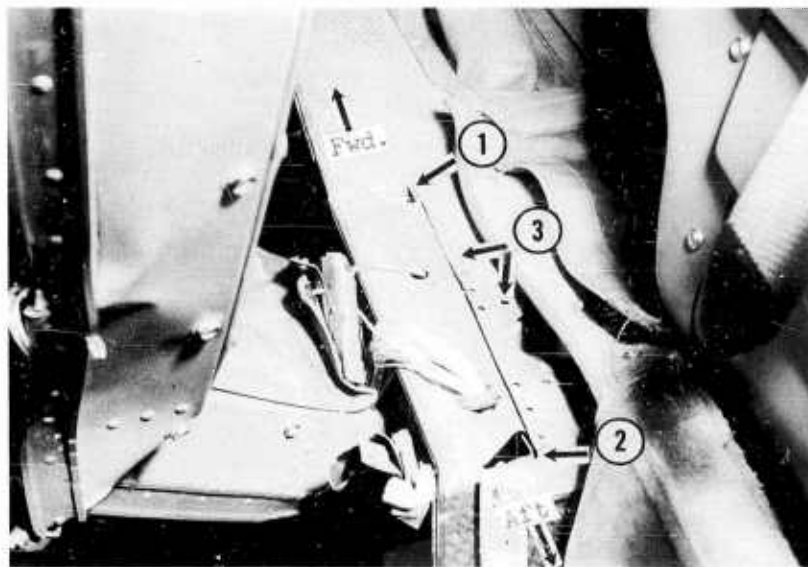


Figure 3. Vertical side support failure in Accident "A". The vertical side support failed at its lower attachment points. The triangular cutouts (arrows 1 and 2) allow the "L" stringers to pass through the floor vertically. The "L" stringers and the inner and outer skin of the support member attach the member to the fuselage. The line of rivet holes (arrow 3) indicate where the skin attaches to the floor.

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Figure 4. Upper attachment failure of the left vertical side support in Accident "A".

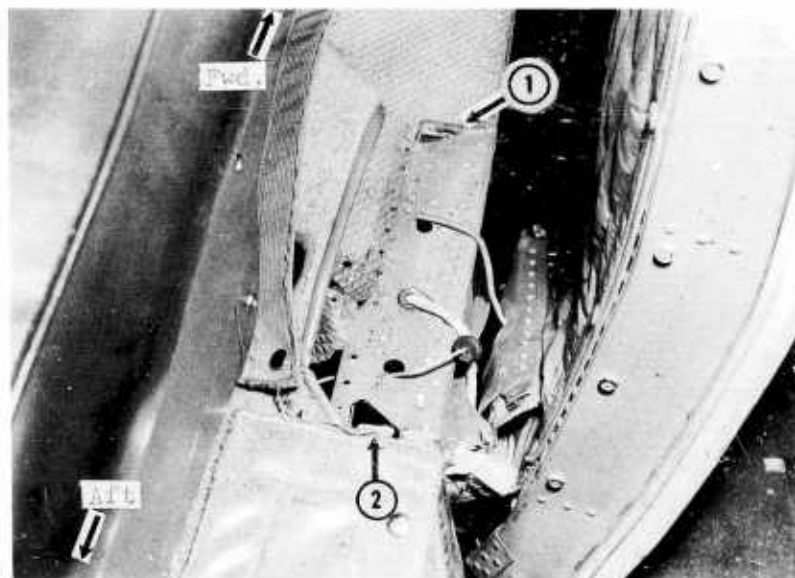


Figure 5. Right vertical support member, lower attachment point, failure in Accident "A". Depth and type of failure of the forward "L" stringer is shown by Arrow 1 (as compared to that of the aft "L" stringer). Arrow 2 indicates some application of force against the upper area of the member in an aft direction during its failure.



Figure 6. Right side support failure in Accident "B". The upper right side support (arrow 3) was torn free, the bottom also failed. Arrow 1 depicts the pilot's right anti-torque pedal, Arrow 2 damage to collective pitch, while Arrow 4 denotes a hole in the roof caused by the pilot's seat as the roof collapsed.



Figure 7. Left side support failure in Accident "B". Arrow 1 depicts the failure on the bottom of the left side support. The top remained attached. Arrow 2 depicts the broken seat attachment, Arrow 3 shows the bent seat tube support.

SECTION I

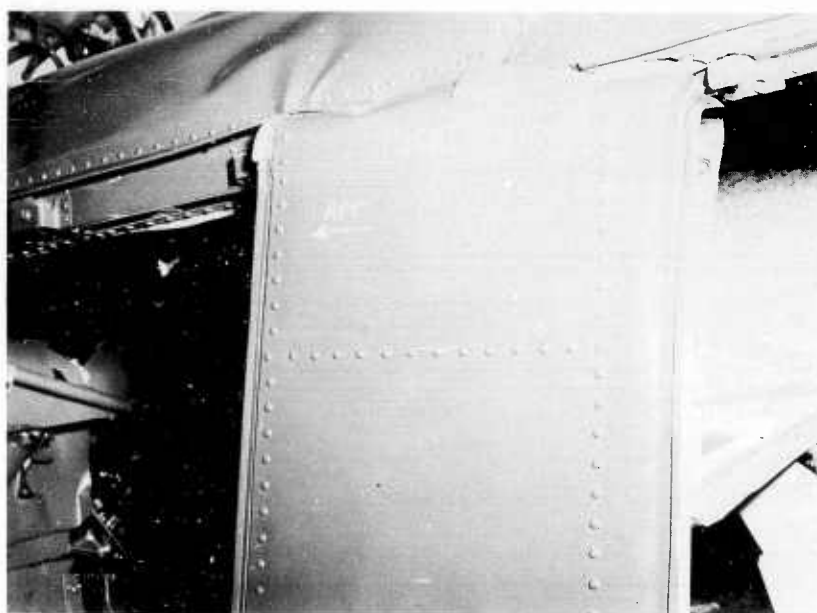


Figure 8. Failure sustained by the top of the right side support in Accident "C".

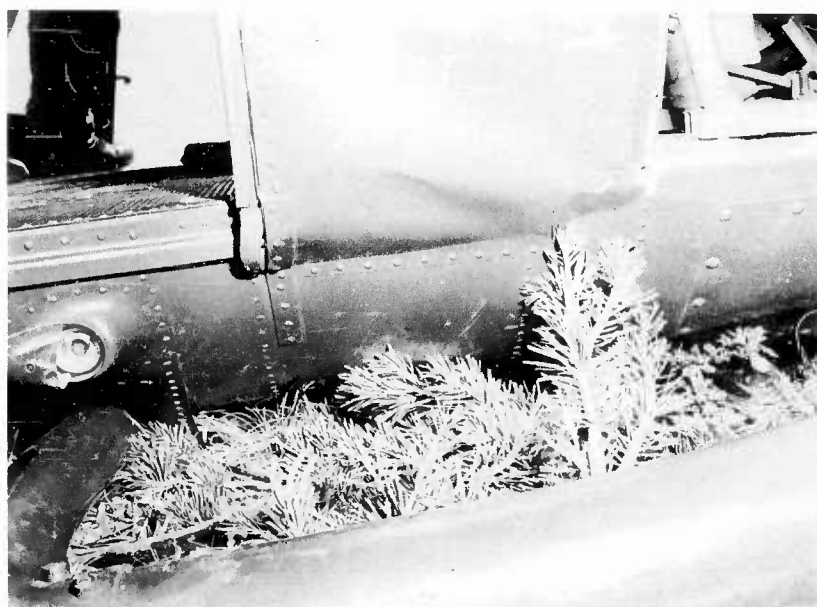


Figure 9. The bottom right side support partially failed in Accident "C".

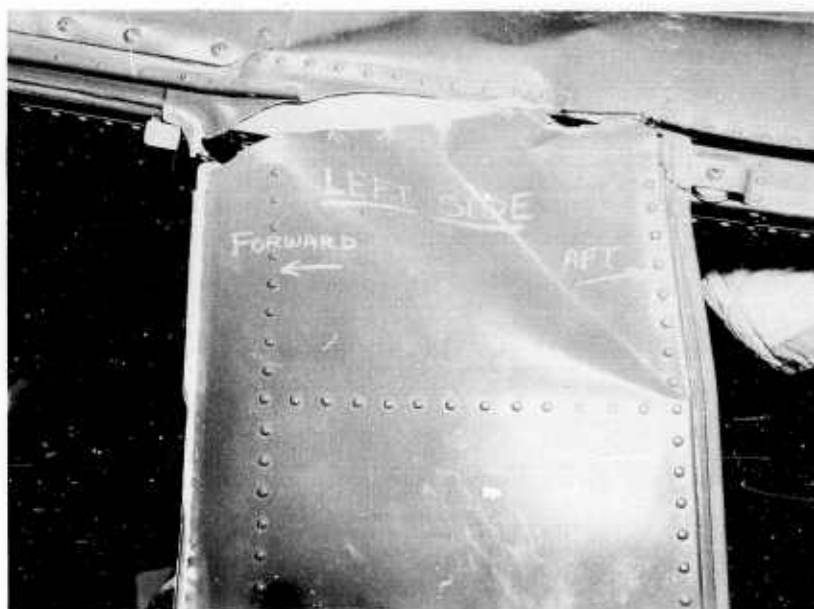


Figure 10. The top of the left side support failed in Accident "C".

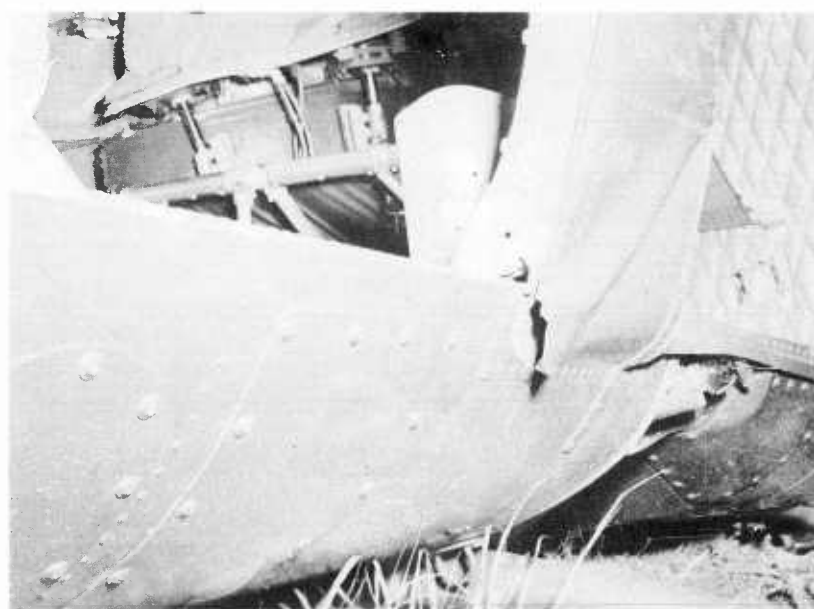


Figure 11. The bottom of the left side in Accident "C" showed signs of failure.



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Figure 12. The top left vertical side support was torn completely free in Accident "D".



Figure 13. The entire left side support in Accident "D" was torn free with the exception of the wiring.



Figure 14. Side view of the torn free support in Accident "D", left side.



Figure 15. The top of the right side was supported by the wiring, Accident "D".

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Figure 16. Wiring supported the bottom on the right side support in Accident "D".

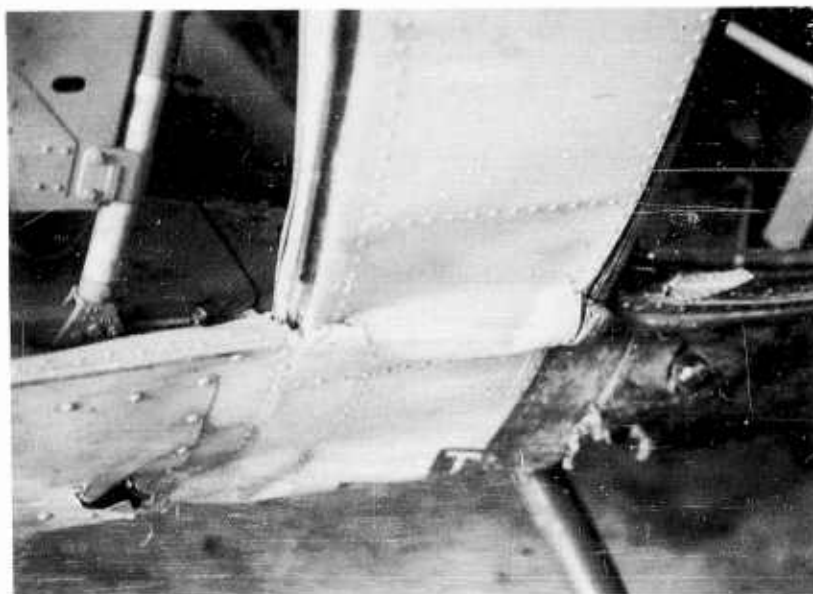


Figure 17. Bottom of the left support in Accident "E" (aircraft fell on its left side). Partial failure may be noted in the side supports.

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Figure 18. Partial failure occurred on the top of the support, left side, in Accident "E".



Figure 19. The downward collapse of the roof in Accident "A" is shown. The dotted line depicts the normal position of the fire wall.

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Figure 20. The collapse of the aft bulkhead allowed the roof structure to impinge into the occupiable area in Accident "B".



Figure 21. The arrow depicts the forward movement of the aft bulkhead, left side, in Accident "C".

Figure 22. The aft roof structure failed on the right side in Accident "C".

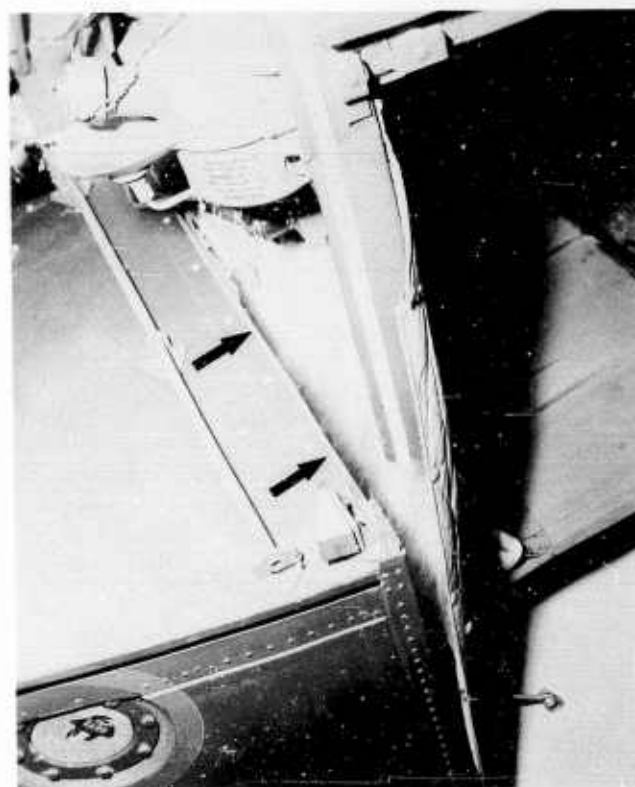


Figure 23. Wiring was the remaining support of the roof structure in Accident "D".

## SECTION I



Figure 24. The forward displacement of the aft roof support is depicted by the arrow, Accident "D".

It is evident, therefore, that the strength requirements of both the main side supports and the aft bulkhead support are inadequate. They should be able to withstand impact forces and conditions of a survivable nature without gross failure. This apparently has been recognized recently by both the military and the manufacturer. "Requests for Alteration" have been studied by the Bell Helicopter Corporation on each of these two features.

The following is quoted from the Bell study of vertical support:

"Request For Alteration No. 12 requested that the contractors study the problem of adding vertical support members to prevent collapse of the roof structure upon occupants during a crash landing of survivable "G" forces. As a result of these studies, it is the opinion of the contractor that the most logical approach would be one of making a general increase of gauge thickness of the sheet metal structure of the door post to increase its column load capabilities. The weight increases per helicopter would be approximately 3.5 pounds. The column strength would increase from 1,750 pounds to 2,690 pounds



## SECTION I

per door post for a total increase of strength of approximately 54%. This change could be accomplished on production HU-1B's and does not involve serious tooling problems. A second approach which the contractor investigated was the addition of a roll-over structure to the pilot and copilot seats. This change would add approximately 3.5 pounds per helicopter, and would provide structure capable of withstanding a vertical load of 3,500 pounds per seat. This change could be incorporated into production aircraft or retrofitted to aircraft already built with changes to the seat assembly."

The Bell study commented as follows on the aft bulkhead:

"Request For Alteration No. 11 submitted during Reference (a) requested that the contractor study the aft cabin bulkhead to improve the structure. As a result of these studies, the contractor is of the opinion that the most logical approach to improving the strength of this bulkhead would be to change the structure above W. L. 54 to a honeycomb type structure. In order to affect this change, it would be necessary to make extensive tooling changes, such as fabrication of a bonding fixture, and to re-engineer the mounting of those items such as hydraulic and electrical equipment which are attached to the bulkhead. By changing the sheet metal structure to honeycomb type construction, the pure vertical load carrying capability of the bulkhead would be increased from 14,900 pounds to 35,000 pounds. It should be noted that these are comparative figures only and do not take into account lateral or fore or aft displacement of the bulkhead under crash loading conditions. Displacement of the bulkhead would materially reduce the vertical load capability of the bulkhead; therefore, the two crash load capabilities of the bulkhead can not be calculated."

The Request For Alteration No. 12 in regard to increasing the gauge thickness of the sheet metal structure of the vertical side supports has been approved and is being incorporated into the HU-1B. It is suggested that the second approach, the addition of the roll-over structure, be studied for retrofit of all HU-1A aircraft presently in service.

Request For Alteration No. 11 also has been approved and will be incorporated in the HU-1B beginning with ship No. 47.



## SECTION I

### AFT FUSELAGE

The aft fuselage incorporates the propulsion system, consisting of the engine and drive system, and the tail boom.

The engine and transmission are located aft of the cabin and mounted above the fuselage on a platform which provides footing for maintenance personnel while servicing the helicopter. They are enclosed by cowling that can be quickly opened or removed for easy access. Use of this type of drive system, with its independent mounted units and quick disconnect couplings, allows rapid servicing, repair or replacement under combat conditions. This results in maximum availability of the helicopter for mission accomplishment.

The tail boom is a semi-monocoque structure with metal covering and is attached to the forward section with bolts to allow easy removal.

The transmission and the engine in this aircraft are stressed for the following loads: 4.5G down; 1.5G side; 8.0G forward; and 2.0G up.

Normal anticipated crash loads can cause the transmission unit to break free and pass downward through the bulkhead into the cabin, striking occupants.

Engine mount failure may cause the engine to push the transmission through into the cabin.

(Both of these hazards were cited in the initial evaluation of the XH-40 mock-up; the transmission hazard was cited also in the USABAAR evaluation of the YH-40 test model.)

It is interesting to note that in the five accidents covered in this report, two of the transmissions were torn completely free (Figures 26 and 29) while partial failure occurred in the remaining three (Figures 25, 27, and 30). Also, it should be noted that in Accident "C" the transmission penetrated the occupiable area to a depth of 17 inches (Figure 28). Here the occupant seated directly ahead of this penetration was extremely fortunate in that his seat failed and his safety belt was loosely adjusted causing him to move forward and down away from the jagged metal on the transmission.

The transmission mount also was cracked in the wreck of the YH-40 at Fort Rucker.

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Figure 25. The arrow depicts the failure in the transmission mount which occurred in Accident "A". The transmission, mast, and rotor assembly were partially torn free as a unit.



Figure 26. The entire unit was torn free when the blades contacted a tree in Accident "B". The arrow depicts the area normally occupied by the transmission.

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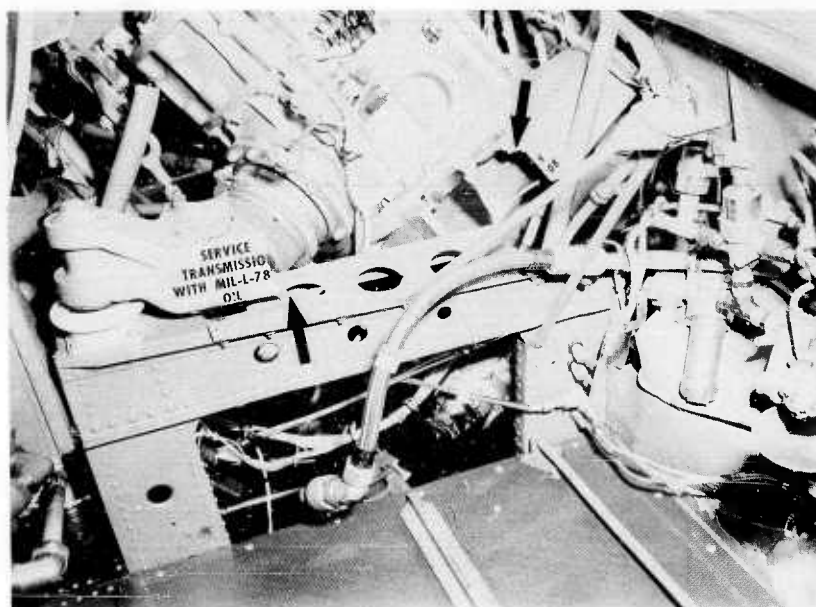


Figure 27. The arrows depict the fractures in the transmission mounts which occurred in Accident "C".



Figure 28. In Accident "C" the transmission penetrated 17 inches into the occupiable area. The loosely worn safety belt plus the failure of the seat permitted the occupant to bottom as depicted in this posed photograph.

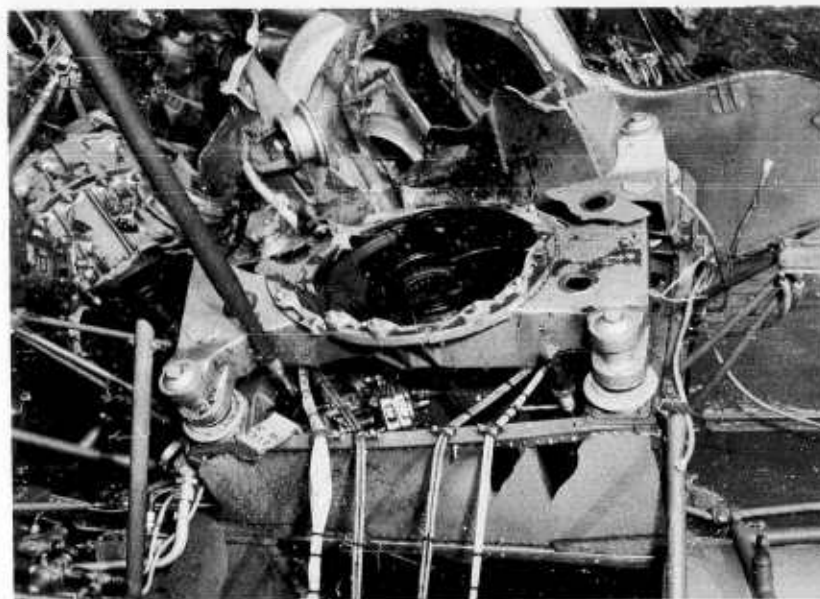


Figure 29. The entire transmission was torn free in Accident "D".

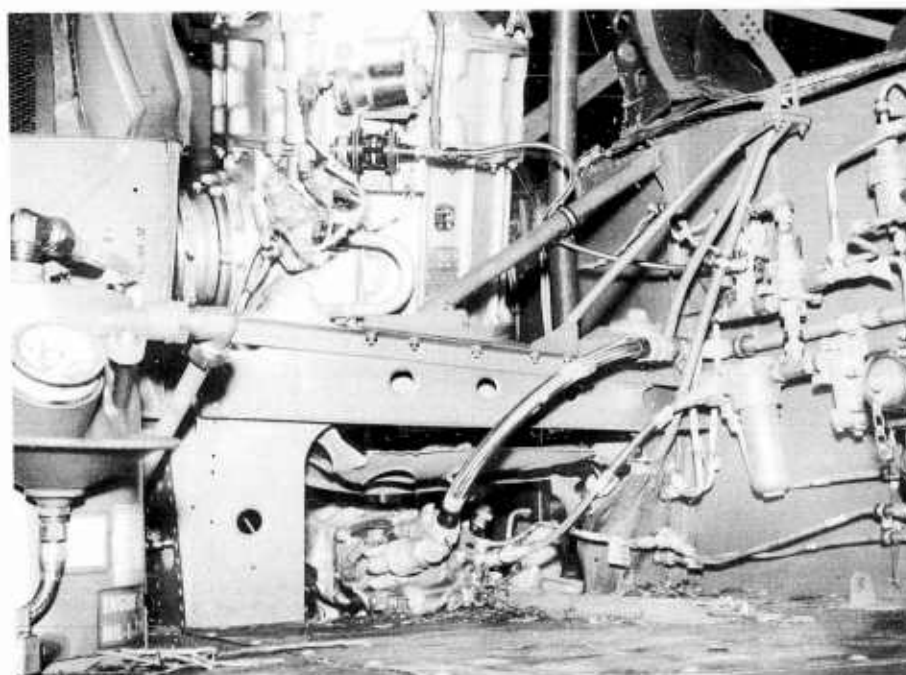


Figure 30. The transmission was displaced in Accident "E".

## SECTION I

As for engine mounts, the engine tore completely free in Accident "A" (Figure 31); partial failure occurred in Accident "B" (Figure 32) and in Accident "D" (Figure 33). No failures occurred in the other two.

Considering the loads for which the transmission is stressed and the fact that a failure occurred in every accident including the YH-40 at Fort Rucker, it is believed that an inherent deficiency in structural design exists.



Figure 31. The arrow depicts the engine, torn free, in Accident "A".



Figure 32. A partial failure in the engine mounts occurred in Accident "B".



Figure 33. The arrow depicts a partial failure in the engine mounts in Accident "D".

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This report concurs in principle with the following two recommendations previously made:

### Recommendation

"It would appear desirable to install tension cables (cables or tubes) between the top of the transmission cage and the aft end of the work platform in order to moderate the transmission unit "peeling" off its base mount. It may also be desirable to use higher strength factors in the design of the rear mounts in order to assist the transmission unit tearing free in an aft direction as torsional loads are applied due to blade damage. "  
(AvCIR - 1955)

### Recommendation

"That some means be provided to insure that the transmission fails (mounts or bolts) away from the occupant to reduce the possibility of injury. "  
(USABAAR - 1958)

Actually, all failures have been associated with the magnesium cradle on which the transmission rests rather than in the mount itself.

## CONCLUSIONS

After analysis of the basic airframe and components, the following desirable crash safety features were noted:

1. The skid-type landing gear incorporates energy absorption capabilities;
2. The location of the fuel tanks offers crash injury protection from a post-crash fire; and
3. The exits in the aircraft are adequate.

Several undesirable features which have or can contribute to occupant injury also were noted:

1. The vertical side supports will buckle or collapse and the aft roof support will fail under crash forces well below survivable limits. This results in the roof impinging upon the occupiable crew and cabin areas with serious effects;



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2. The tie-down strength of both the transmission and the engine is inadequate. Failure at crash force levels well below survivable limits may result in the transmission being projected through the aft bulkhead into the occupiable cabin area;
3. The absence of operating instructions on the exterior of cabin doors could increase the exposure time on the occupants in the event of a post-crash fire; and
4. The absence of exterior markings in regard to the location of the hand fire extinguisher also could increase the exposure time in the event of a post-crash fire.

### RECOMMENDATIONS

Based on the foregoing conclusions, the following recommendations are made:

1. The following elements should be redesigned to provide increased strength requirements compatible with survivable crash force magnitudes, directions, and time duration:
  - (a) vertical side supports;
  - (b) the aft roof support; and
  - (c) transmission and engine installations, particularly the transmission.

The vertical side and aft roof supports are being strengthened plus the addition of a fifth transmission mount are being incorporated in the HU-1B. However, if this modification is not practical it is then suggested that consideration be given to the installation of a suitable roll-over structure in all HU-1A aircraft to prevent the roof structure from collapsing downward into the occupied area of the aircraft;

2. The exterior of the main cabin doors should be placarded as to the method and direction of operation with letters large enough and with sufficient contrast to be easily recognized as an escape area by untrained rescue personnel; and
3. Exterior markings giving the location of the fire extinguisher should be added.



EVALUATION OF CREW COMPARTMENTGENERAL DISCUSSION

This aircraft contains a well-designed and spacious cockpit. Maximum visibility is afforded the pilot and crew by extensive use of transparent panels at the top, front, bottom, and sides of the cabin. The noise and vibration levels in the cockpit are considerably less than in helicopters utilizing reciprocating engines.

The instrument panel is well arranged as is the console located between the pilots' seats. It is felt that the panels are located sufficiently forward to preclude being struck by either occupant, provided the restraint system (safety belt and shoulder harness) is utilized and the seat tie-down does not fail.

It should be noted that the lower edges of the instrument panel (Figure 34) are quite sharp and unprotected. Statistics reveal that the lower extremities receive the second largest percentage of injuries. The lower edges of the instrument panels should, therefore, be padded with a high energy absorbing material.

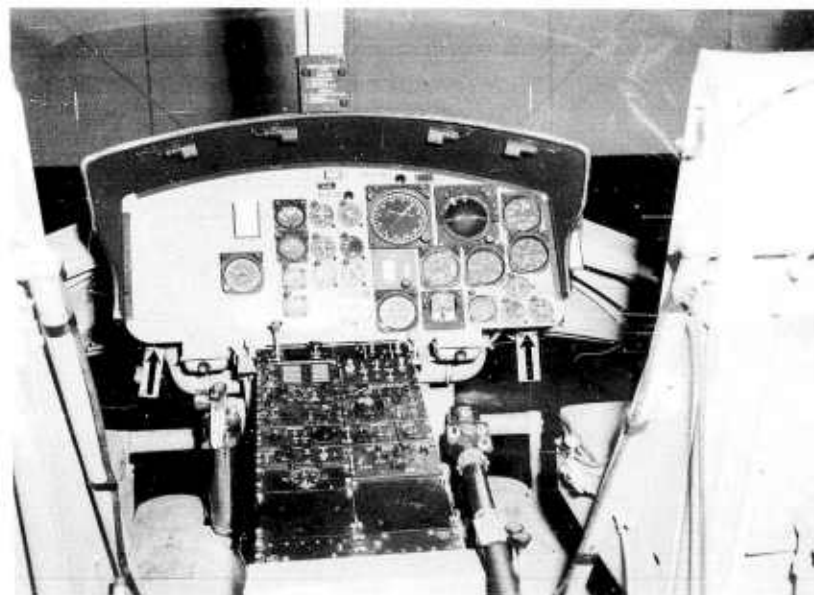


Figure 34. Over-all view of the instrument panel in the HU-1 and HU-1A. The arrows denote the sharp unprotected lower edges of the instrument panel.

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### PILOT'S AND COPILOT'S SEATS

The pilot's and copilot's seats are the adjustable non-reclining type, mounted on fixed tracks (see Figure 35). The lever for height adjustment is on the left side of each seat and the fore and aft adjustment lock is on the right side. Each seat is equipped with a lap safety belt and an inertia reel shoulder harness; the inertia reel is attached to the rear of the seat. Design of the seat permits the use of a back-pack parachute or a standard cushion on the back of the seat and either a seat-pack parachute, pararaft kit, or a standard cushion in the seat pan.



Figure 35. A side view of the pilot's seats. The inertia reel manual locking lever is conveniently located on the side of the seat pan (arrow).

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The seat back cushion is shaped to provide maximum comfort and support. The back cushion is constructed of three laminated layers of foam polyurethane and is four and one-half inches thick at the center, two inches thick at the edges.

The seat cushion utilized in this aircraft incorporates desirable energy absorbing qualities. The cushion is approximately six inches thick and consists of five laminated layers. The top layer which is approximately one-half inch in thickness is soft foam rubber. Beneath this layer are two layers of moderately soft ensolite, each approximately one inch thick. The bottom two layers of the cushion consist of a firm ensolite, each layer being approximately one inch thick. By utilizing the various densities of foam rubber and ensolite the occupant is not only provided comfort, but also considerable protection in the event of high vertical forces.

The pilot's and copilot's seats are constructed of sheet metal with a tubular frame supporting structure. The aft portion of the seat pan contains a perforated sheet metal baffle type structure which acts as a spacer to accommodate either a back or seat type parachute or pararaft kit.

During the AvCIR evaluation, conducted in 1955, the following hazard and recommendation was noted:

### Hazard

"Rear portion of seat attachment clip rail is "open" and will permit spreading and loss of seat under forward crash load."

### Recommendation

"Close open end of seat attachment clip rail."

The safety belts on the crew members' seats are attached to the sides as depicted in Figure 36. A reinforcing plate is attached to the outside of the seats for additional strength. It should be noted that this safety belt attachment is not an omni-direction attachment. Helicopters frequently encounter side loads during an accident, and this type of anchorage would have a prying effect on the attachment with possible end attachment failure. It is suggested that the end attachments incorporate a self-aligning omni-directional anchorage.

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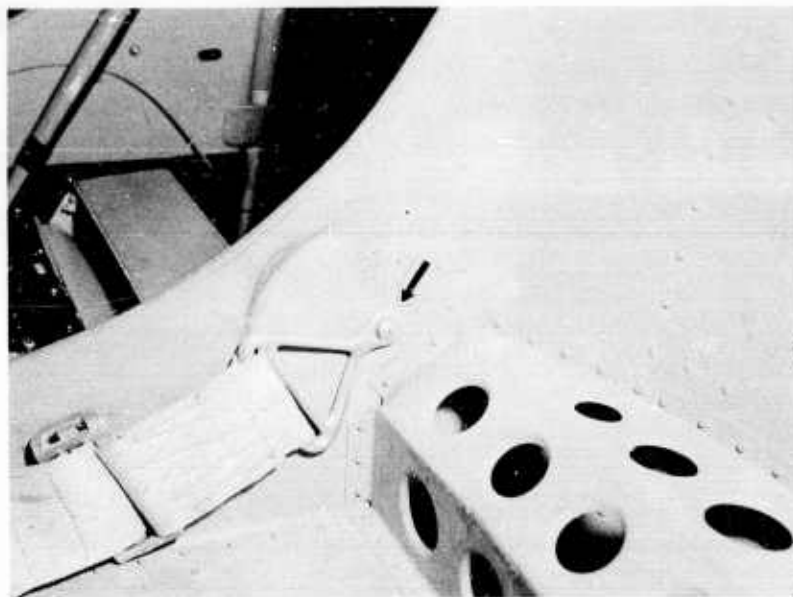


Figure 36. Close-up of the safety belt end attachment (arrow). The metal baffle type structure is also depicted.

The inertia reel and shoulder harness incorporated on the pilot's and copilot's seats is shown in Figure 37. A manual lock-unlock handle is located on the left side of the seats. When the inertia reel control lever is in the unlocked position, the reel cable will extend to allow the pilot to lean forward; however, the reel will automatically lock when subjected to a 2 to 3G deceleration. Locking of the reel can be accomplished from any position and the reel will automatically take up slack in the harness. To release the lock it is necessary to lean back slightly to release tension on the lock and move the control handle to the locked and then the unlocked position. Manual locking of the reel should be accomplished for all emergency landings.

The excessive width of the shoulder harness guide, depicted in Figure 37, permits the occupants entirely too much lateral movement. Again, it must be emphasized that a large number of helicopter accidents involve side load conditions. When this condition exists, excessive width of the shoulder harness guide permits the occupants sufficient lateral movement to strike surrounding structure, such as the cockpit door.

The pilot's and copilot's seats are designed to the following loads: 8.0G forward, 5.0G aft, 15.0G down, 7.5G up, and 10.0G side.

Figure 37. The arrow depicts the inertia reel attached to the rear of the seat. Note the width of the shoulder harness guide at the top of the seat. This is considered excessive.



The shoulder harness is capable of sustaining 4.5G forward while the safety belt is capable of sustaining 5.5G forward. This gives a total of 10.0G forward restraint for each of the crew members' seats.

No pilot or copilot belt failures occurred in any of the five accidents covered.

As previously stated, the shoulder harness with inertia reel for the pilot's and copilot's seats, as shown in Figure 37, is attached to the rear of the seat. This arrangement is not desirable from the crash safety point of view since the effectiveness of occupant restraint depends upon the seat tie-down strength. Attachment of the shoulder harness to basic aircraft structure would relieve the seat of much of the crash load during crash deceleration and offer some degree of occupant protection even when the seat tie-down failed. The advantage of attaching the shoulder harness to basic aircraft structure is unquestionable since it eliminates the torque on the seat exerted by a shoulder harness anchored to the seat. This is considered essential until such time as the seat tie-down criteria more nearly approach the accepted limits of human G tolerance, 40G.

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It is felt that the injuries sustained by three of the occupants, one in Accident "B" and two in Accident "D", would have been considerably reduced had the reels been attached to basic structure. A securely anchored reel probably would have prevented two of the occupants from being thrown through the windshield and considerably reduced the injuries to the third occupant as he was thrown into the pedal well.

The pilot's and copilot's seats in Accident "A" differed from those normally found in operational aircraft. These heavier upholstered seats were individually mounted on large, flat supporting plates with forward and aft adjustment. No failures occurred in the pilot's and copilot's seats in Accident "A" and "C".

A "Request For Alteration, No. 24" to the manufacturer asked that the contractor study the possibility of anchoring the crew safety belt and shoulder harness to some structure other than the pilot and copilot seat. The contractor indicated that the safety belt and shoulder harness could be anchored to the floor structure without involving serious changes to the basic airframe; this arrangement would relieve the seat of almost all forward crash loads. The contractor also pointed out that if this change is incorporated there is the disadvantage of having to adjust the seat belt and the shoulder harness each time the position of the seat is changed.

The operating characteristics of the shoulder harness and inertia reel would not require any adjustment of the shoulder harness with seat adjustment when in the unlocked position. With regard to the seat belt, it is suggested that a survey be made to determine the frequency with which the seats in this helicopter are adjusted during flight to determine whether seat belt adjustment would create a serious problem.

Photographs in Figures 38 through 46 show the seat failures in Accident "B", "D", and "E".

Figure 38. The pilot's seat failed in Accident "B". The arrow points out the failure which occurred at the casting.

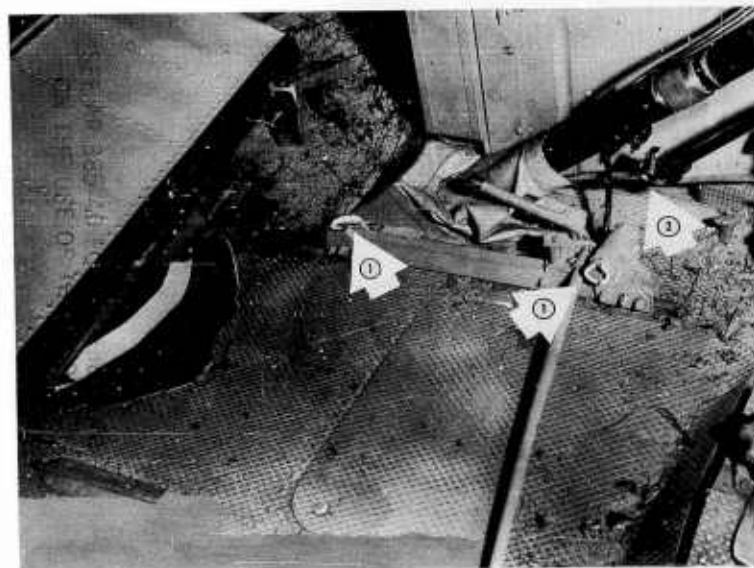


Figure 39. Side view of the failures in Accident "B". The rear attachment failed at the casting (arrows 1) while the front failure occurred at a drilled point in the front cross-tube. Arrow 2 depicts the broken collective pitch.

## SECTION II

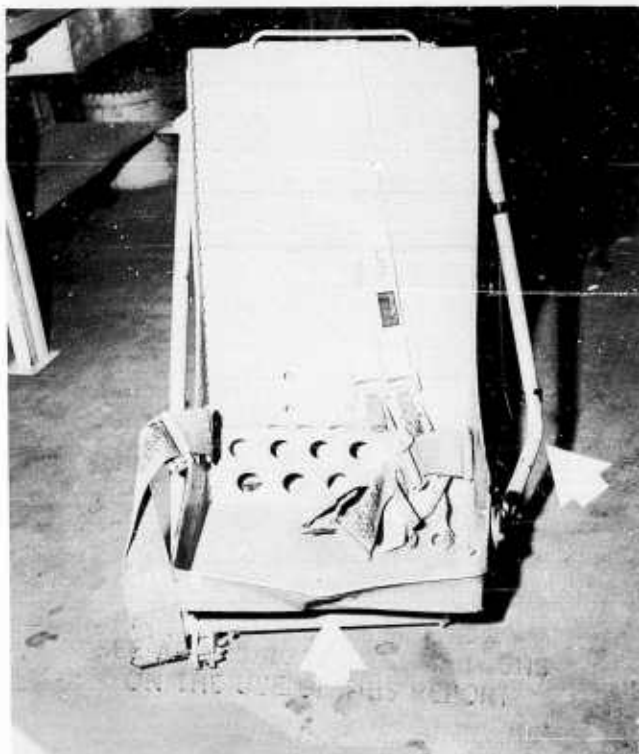


Figure 40. Damage to the pilot's seat pan in Accident "B". The bottom arrow depicts the distortion sustained by the seat pan. The side arrow points out the distortion to the seat tube, Accident "B".

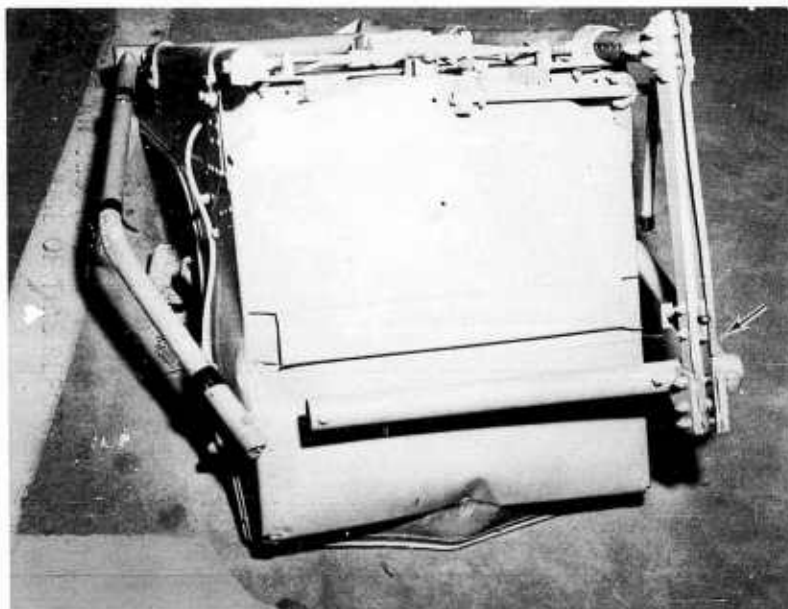


Figure 41. Seat carriage in Accident "B". The arrow depicts the spreading of the seat carriage permitting the seat to separate from the track.



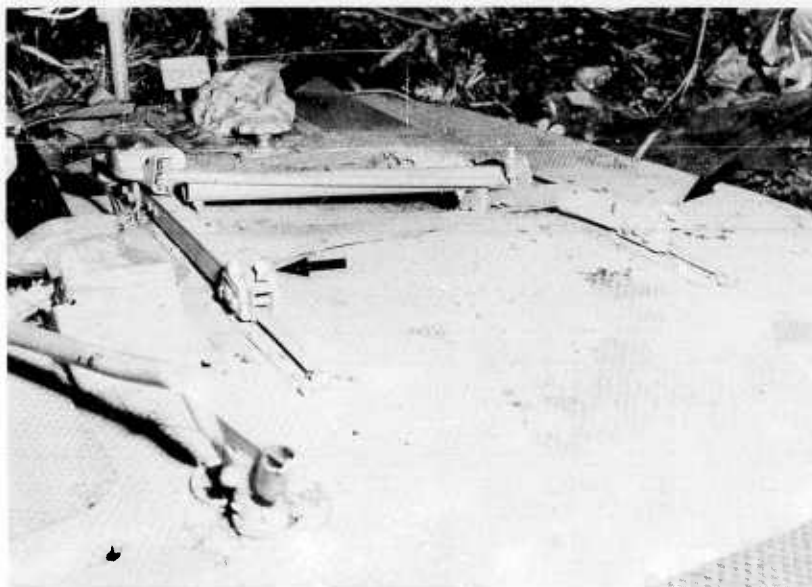


Figure 42. The arrows denote the failures in the leg castings in Accident "D" (right seat). Note the similarity in the failures in this accident with those in Accident "B".

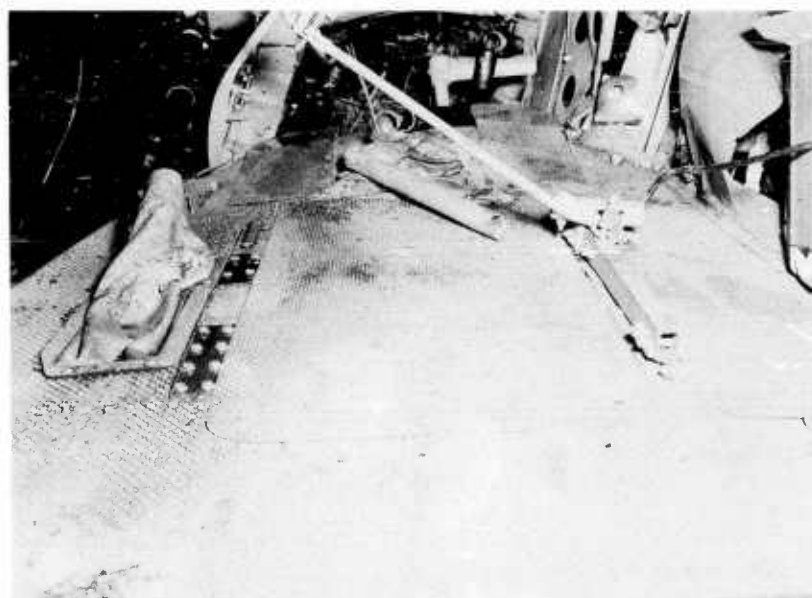


Figure 43. Left seat failure in Accident "D". The right rear leg tore free from the carriage while the left rear leg ripped the track from the floor, permitting the seat to pivot forward. The front attachments were torn free by rescue personnel.

## SECTION II

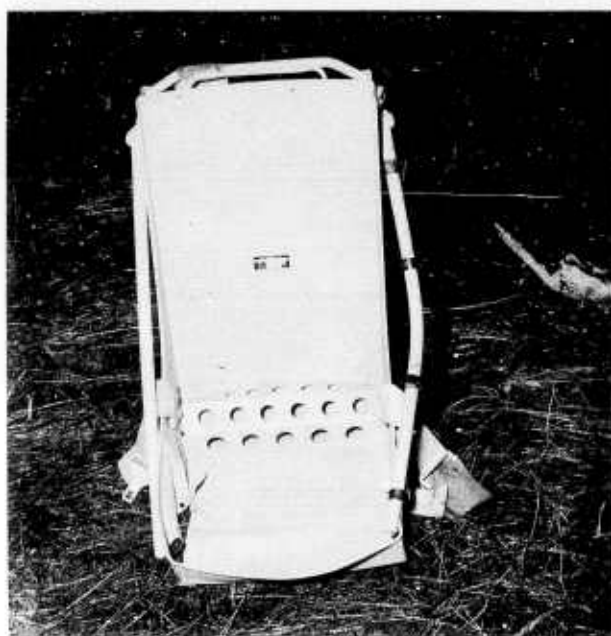


Figure 44. The pilot's seat, right side, in Accident "D". Note the similarity in the damage with the seat in Accident "B".

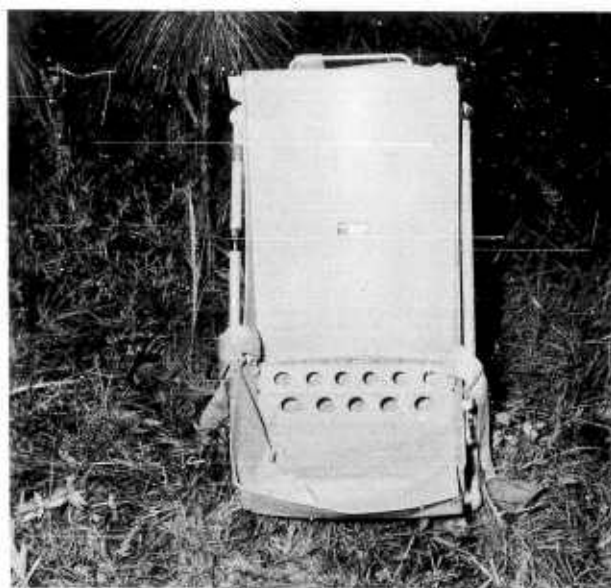


Figure 45. Damage to copilot's seat, left side, in Accident "D".

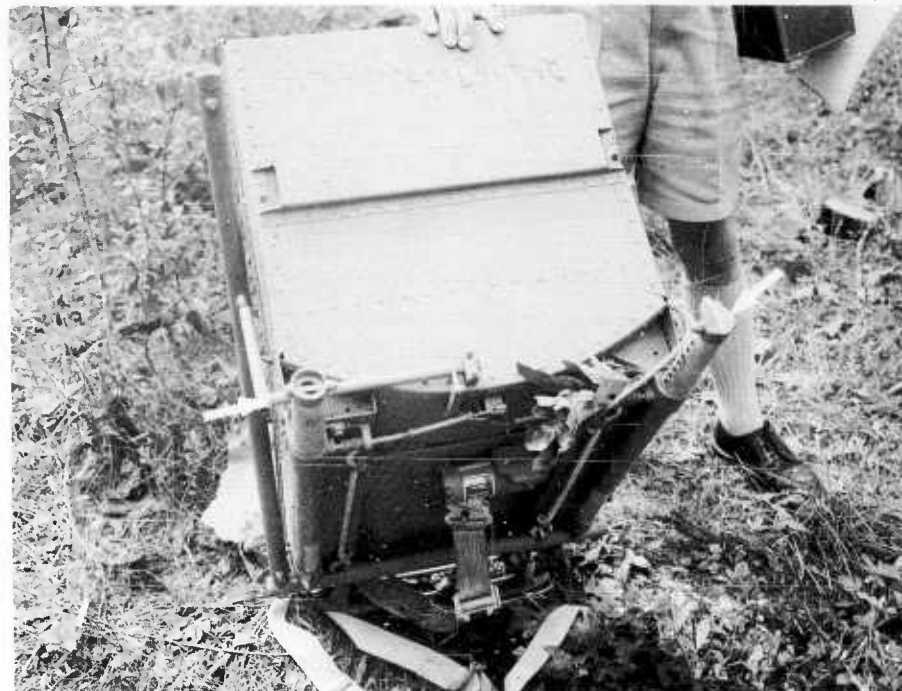


Figure 46. In Accident "E", failures occurred in the leg casting and also at a drilled point (arrows).

#### CREW CHIEF/MEDICAL ATTENDANT SEAT

This seat is located just aft of the pedestal and was primarily designed as an aft facing Medical Attendant seat (Figure 47). In some cases the seat is reversed, forward facing, and is utilized by the crew chief. The safety belt is attached at the junction of the seat back and the seat pan and is stressed for 5.0G aft and 10.0G side loads when utilized in the aft facing position.

The seat and its supporting structure is designed to the following ultimate loads when in an aft facing position (200-pound man): 10.0G forward; 15.0G down; 10.0G side (through belt); 5.0G aft (through belt); and 7.5G up (through belt).

Out of the five accidents, this seat was installed and occupied only in Accident "D". In this case, the seat was attached facing forward and occupied by the Crew Chief. Upon impact the seat tore free from its leg attachments and permitted the Crew Chief and seat to be hurled out through the windshield.

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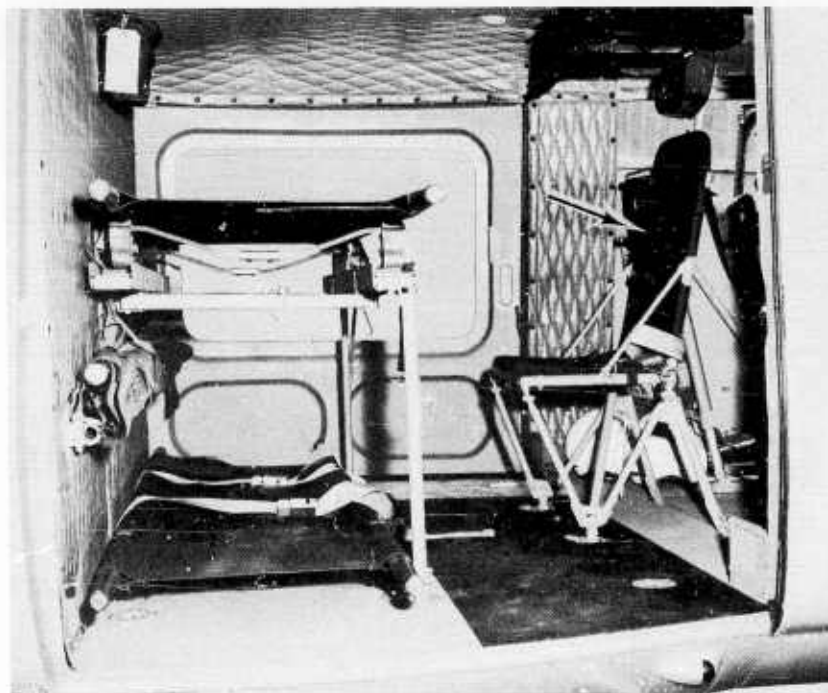


Figure 47. View of the Crew Chief/Medical Attendant seat mounted in an aft facing position (arrow).



Figure 48. Crew chief seat failure in Accident "D". The arrows depict failures of the leg structure.

Figure 49. Damaged crew chief's seat.



The discussion of seat belt and shoulder harness installation on the pilot and copilot seats also applies to the crew chief seat when utilized in the forward facing position.

#### EMERGENCY EXITS

Crew entrance and departure is accomplished through two swing-hinged doors located in the forward cabin area next to the pilot's and copilot's stations. The pilot's and copilot's doors are formed aluminum frames with transparent plastic windows in the upper section. Ventilation is supplied by sliding window panels. Cam type door latches are used and the doors are equipped with interior jettisonable door releases to allow release in flight. The jettison handles are cradled by brackets attached to the forward door post. Pulling the handles operates a cam to pull the hinged pins and depress the door latches to allow the doors to be released from the helicopter. At the present time it is impossible to jettison the cockpit doors from the exterior.

In Accidents "A" and "D" both cockpit doors were torn free. In Accidents "B" and "C" the left door popped open and the right door was partially torn free while in Accident "E" one door was inoperable due to the aircraft lying on its left side, but the right door was operable.

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At the present time, with the exception of outside emergency releases, it is felt that the emergency exits in the cockpit area are adequate.

### CONCLUSIONS

Based upon the foregoing evaluation of the crew compartment, it is concluded that:

1. The sharp lower edges of the instrument panel could contribute to lower extremity injuries;
2. The seat back and the seat cushion provide adequate comfort and protection to the crew members;
3. The safety belt does not incorporate a self-aligning omnidirectional anchorage;
4. The seat belt is attached to the seat instead of to primary structure and, therefore, the safety belt does not provide maximum possible protection;
5. The inertia reel is attached to seat instead of to primary structure and, therefore, the shoulder harness does not provide the maximum possible protection;
6. The shoulder harness guide on the crew seats is too wide;
7. The tie-down requirements for the pilot and copilot seats are inadequate;
8. The tie-down requirement for the Crew Chief/Medical Attendant seat is inadequate; and
9. The absence of exterior emergency releases could increase the exposure time in the event of a post-crash fire.

### RECOMMENDATIONS

Based upon the evaluation of the crew compartment, it is recommended that:

1. The lower edges of the instrument panel be padded with an energy absorbing material;

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2. The present safety belt anchorage be changed to a self-aligning omni-directional attachment;
3. The seat belt be attached to primary structure;
4. The inertia reel on the pilot and copilot seats be attached to primary structure;
5. The shoulder harness guide be reduced to a minimum width;
6. The Military Specification dealing with the tie-down requirement for the pilot's and copilot's seats be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration;
7. The Military Specification dealing with the tie-down requirement for the Crew Chief/Medical Attendant's seat be revised to provide strength requirements compatible for survivable crash force magnitudes, directions, and time duration; and
8. Equip both pilot and copilot cockpit doors with outside emergency door mounting releases to permit jettisoning of doors regardless of distortion or damage to the doors and/or adjacent cabin structure.

EVALUATION OF THE MAIN CABINGENERAL DISCUSSION

The passenger-cargo cabin area in this aircraft contains two, two-man troop seats that are foldable and stowed against the aft cabin bulkhead. When the seat is folded, the area presents an unrestricted loading space for cargo or equipment transportation. For ambulance or mercy mission service, a litter rack and medical attendant seat are quickly installed and two litter patients can be carried within the cabin.

Entrance and exit from the cabin area is possible through two large sliding cabin doors, one on each side of the aircraft. These large cabin doors are track-mounted and operate in a fore and aft direction. At the present time it is impossible to jettison these doors from either the interior or the exterior. The large kick-out windows in the cabin doors would provide an escape route in the event the doors became jammed.

TROOP SEATS

The troop seats are arranged along the rear cabin wall and face forward. The seats are designed to be folded and stowed against the rear cabin wall when not in use.

The seats currently being utilized were built in accordance with the strength requirements of MIL-S-5804 and will sustain the following loads: seat bottom - 11.0G; seat back - 3.0G; forward seat tube - 1.1G; and leg load - 5.0G.

The seat pan consists of a nylon fabric which is attached to the forward and rear seat support beam. The seat pan folds around the rear support beam and is sewn and riveted to the underside. The seat pan is attached to the forward seat support beam by means of screws and reinforcing strip.

The seat back consists of nylon webbing straps which are sewn to the seat pan on the lower end, and extended from the upper seat support beam by the use of clips. The seat back is pulled taut by means of adjusters.

The forward seat support beam is separated from the rear support beam by a spreader which clamps between the two beams. The seat legs are attached to the forward support beam by an encircling clamp with a friction lock and anchored to attachment points in the floor.



### SECTION III

Accident experience has shown that the currently utilized troop seat fails structurally when subjected to relatively moderate crash forces. When seats of this design fail, numerous injuries have been experienced as a result of broken, exposed ends of the tubing coming into contact with occupants, occupants being thrown free and coming into contact with other occupants and/or various parts of the aircraft.

In the five accidents covered in this report, 80 percent of the occupied troop seats sustained either a partial or complete failure indicating an inherent weakness in the seat design. The load-carrying capabilities of these seats are considered unrealistic when an 11G seat bottom is attached to a 1.1G forward seat tube. The testing procedures are also considered inadequate. The following test procedure is quoted from a manufacturer supplying these seats:

- "A. Install the troop seat in an appropriate aircraft.
- B. Apply body weight to the seat assembly at various points to check structural rigidity."

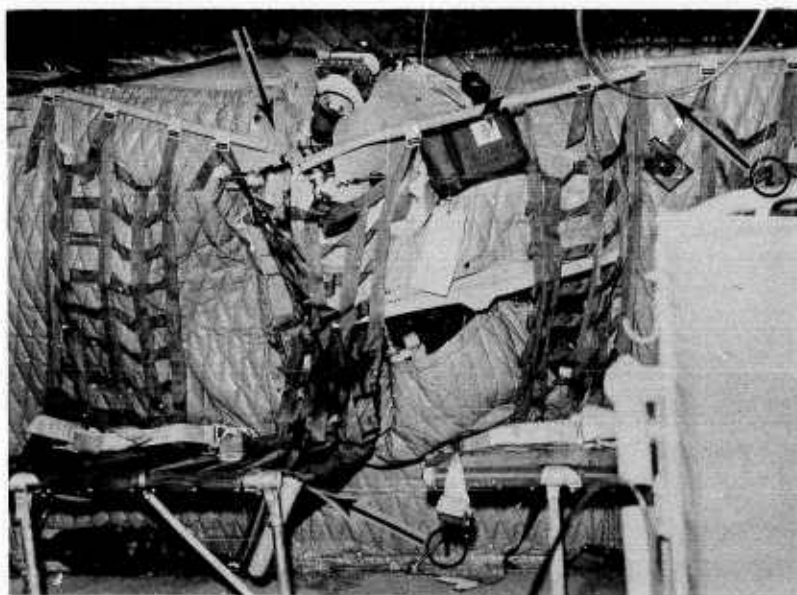


Figure 50. Cabin seat failure in Accident "C". Arrow (1) denotes the failure in the forward cross-tube. Failures also occurred in the cross-tube which supports the seat back due to the penetration of the transmission (arrows 2, 3).

### SECTION III

Accident experience has proven that MIL-S-5804A requires revision to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration. Furthermore, the troop seat should be subjected to dynamic testing in order to obtain a more realistic appraisal. The cabin area in Accidents "A" and "B" was unoccupied; therefore, no seat failures occurred. In Accident "E" the seats were folded and replaced with a ferry tank.

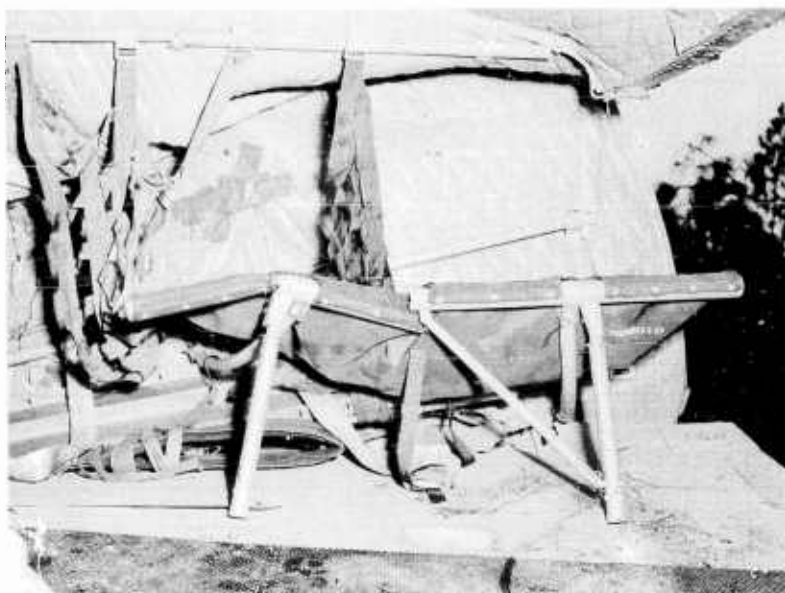


Figure 51. In Accident "D" both seats on the left side were completely collapsed and broken. The seat was set up for photographic purposes.

### SECTION III



Figure 52. The right side cabin seats in Accident "D" were broken.

Numerous investigations and evaluations have shown that the cabin occupants' seat belts are being attached to an "O" ring which is attached to a rear longitudinal seat support. The correct and incorrect manner of attaching the seat belts in this aircraft is depicted in Figures 53 and 54.

The belts are stressed to withstand 11.0G at a 45-degree angle upward, forward, and inboard. The seat belts should be attached to the cables which are tied directly into primary structure (Figure 54).

To fully utilize the skeletal strength of the human body, the seat belt should pass across the hips approximately 45 degrees to the longitudinal axis of the airplane. When restrained by a seat belt only, which is common in the cabin area, the occupant's body will flex over the seat belt during a forward deceleration. If this flexing of the body occurs at the lumbo-sacral joint, the strain on the spine will be minimal.

When the seat belt is attached to the "O" ring, Figure 53, the spine is forced to bend or flex at a much higher level which often causes flexion fractures of the spine.

The incorrect belt installation also permits the seat belt to "ride up" and could cause rib and/or chest injuries due to flexing over the belt buckle, in addition to possible spinal injuries.

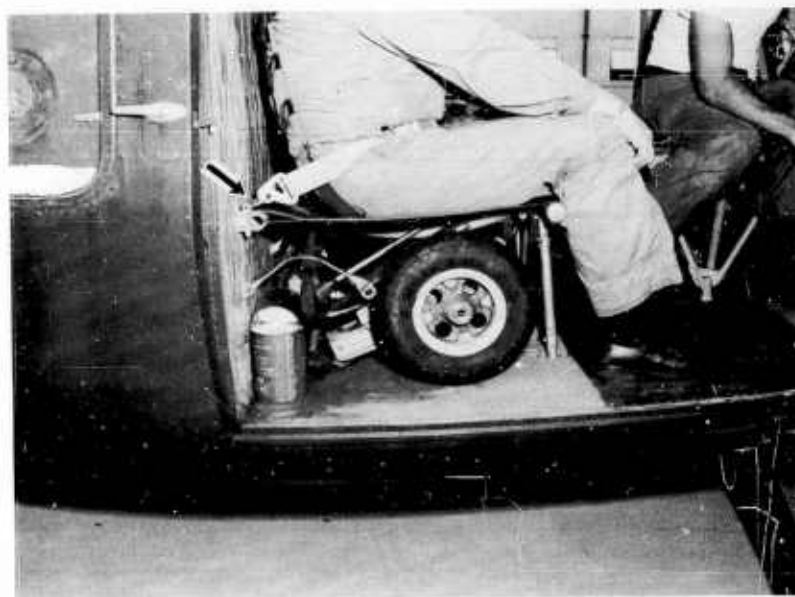


Figure 53. The incorrect method of attaching the safety belt to the "O" ring is depicted by the arrow. Note that the belt crosses the occupant at approximately 90°.



Figure 54. The correct manner in which the safety belt should be installed in the HU-1 and the HU-1A is depicted by the arrow. Note that the belt crosses the hips at approximately 45°.

### SECTION III

The following is a quote from the evaluation conducted November 1955:

#### Hazard

"Safety belt anchorages are incorrectly positioned, causing belts to ride above the hip bone and below the rib cage. This position normally will cause severe and/or fatal internal injuries in a survivable type crash."

#### Recommendations

"Locate belt anchorages so that the safety belt web crosses the lateral aspects of the hip bones at 45 degrees to the horizontal (in the XH-40's this anchorage point will be approximately at the intersection of the bottom of the bulkhead and the floor)."

In the evaluation conducted by USABAAR in November 1958, the following is quoted:

#### Findings

"Safety belt anchorages are incorrectly positioned, causing belts to ride above the hip bones and below the rib cage."

#### Recommendation

"To locate the safety belt anchorages so that the safety belt crosses the lateral aspects of the hip bones at 45 degrees to the horizontal."

### LITTERS

To date there has been no accident experience involving litters; therefore, it is difficult to evaluate the entire litter installation in terms of crash-worthiness. Apparently, utilized litters are considered "field exchange" items in the military system. Of necessity, then, such litters must be strong, rugged items of equipment for use under field and combat conditions and must be suitable for use not only in aircraft, but also in ambulances, field hospitals, etc. Unlike components designed specifically for use in air vehicles, the litter itself is extremely heavy, bulky, and presents many injurious structures when utilized in the manner required for mass evacuation of injured in transport or helicopter type aircraft. Considering

### SECTION III

that helicopter accidents are usually associated more with vertical and side loading than with longitudinal loading, the current minimum strength requirements do not seem to be realistic or compatible with the condition anticipated during even minimal crash deceleration. In addition, litter patients are normally restrained in relatively loose fashion and are likely to "bottom out" against their restraining system (belts, etc.), under dynamic crash force application, thereby magnifying crash forces which in turn are transmitted to the structures.

Litter installation requirements (MIL-S-5705, USAF, Appendix II) provide that supports and attachment fittings for litters shall be designed so that they will carry to the primary structure a 250-pound litter load, multiplied by the following ultimate load factors: forward - 8.0G; side - 1.5G; vertical - 4.5G; and down - 2.0G.

While the adequacy of even 8G strength in the forward direction is questionable, the side and vertical minimum strength requirements should be at least equal in helicopters.

Consideration should be given to re-evaluation of current minimum strength requirements as presented in MIL-S-5705 (USAF), and these requirements should be increased to a point where they are compatible with anticipated crash load conditions.

The current litter configuration and installation should be dynamically tested with full-scale anthropomorphic dummies under force magnitude, direction, and time history conditions associated with survivable crash loads sustained in helicopter accidents. The results of these tests should be utilized in the development of a more suitable specification.

### SECTION III

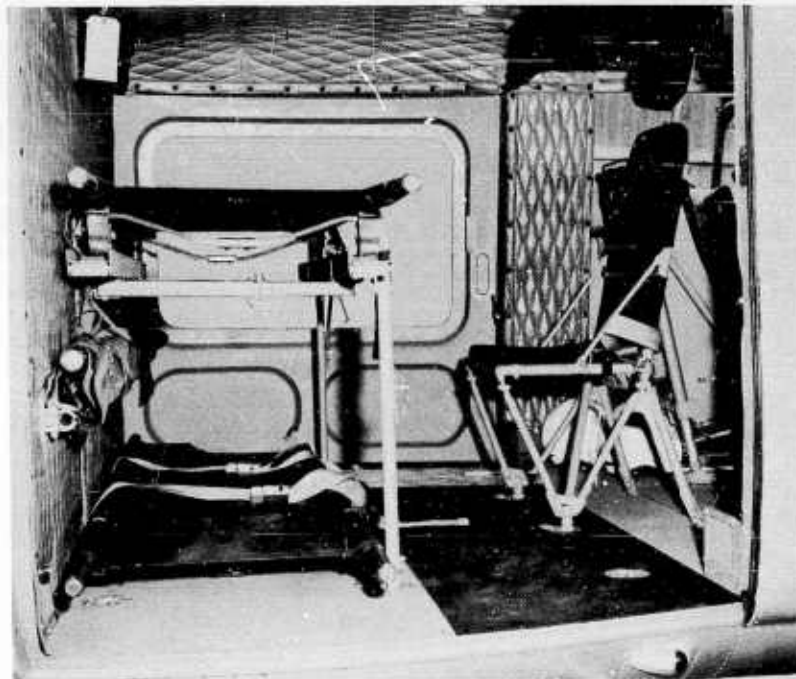


Figure 55. Over-all view of the litters and supporting frame.

The following hazards and recommendations are quoted from the evaluation conducted November 1955:

#### Hazard

"The litters are not securely attached, their attachment depends on the tightness of the safety belts around the patients."

#### Recommendation

"Attach litters securely and positively to structure to withstand side, forward, upward, and downward load."

#### Hazard

"Heavy vertical loads will cause the patients to bottom against the cross beams in the litters, the cross braces in the mount structure, and against the rigid floor structure below the bottom litter."

Recommendation

"Design litter mount structure to deform under body impact loads, rigid structure which cannot be redesigned to be padded with energy absorbing materials or incorporate metal pans in the mount structure shape D to conform with, and parallel, the cross-sectional shape of the litter cross members. "

Hazard

"The vertical support tubes are hazardous in relation to impact injury and entrapment in kinking action. "

Recommendation

"Eliminate present support tubes, or relocate further outboard to prevent their being hit by the litter patient; in suspension mounts or tubes running from the top of the rear bulkhead might be preferable; a diaphragm or net might be used from the bulkhead or from the roof downward to the forward edge of the litters. This would permit wide distribution of longitudinal crash loads on the litter patients. "

Hazard

"The litter safety belt anchorages on the bulkhead are improperly positioned and can cause serious injuries to the litter occupants. "

Recommendation

"Lower anchorage hardware to a non-dangerous area. "

The following finding and recommendation is quoted from the evaluation conducted by USABAAR in November 1958:

Finding

"Litters cannot be securely attached; their attachment depends on the tightness of the safety belt around the patient. "



### SECTION III

#### Recommendation

"Attach the litters securely and positively to structure to withstand side, forward, upward, and downward load."

#### EMERGENCY EXITS

Entrance to the passenger-cargo area is effected by means of two large sliding doors, one located on each side of the aft cabin area (Figure 56).

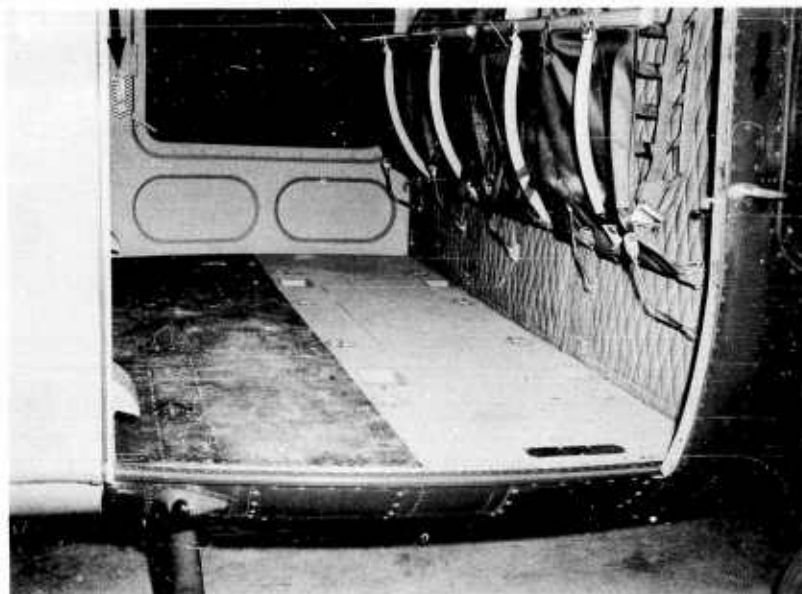


Figure 56. Absence of exterior door operating instructions. The arrow on the left depicts the interior operating instructions. The arrow on the right denotes the absence of exterior door operating instructions.

The large doors permit rapid entrance and departure during combat conditions. In order to prevent inadvertent opening during flight the cabin doors are not jettisonable. In the event of an accident where the doors were rendered inoperable, the large window could be broken or kicked out to provide an avenue of escape. At the present time, however, there are no operating instructions on the exterior of the door to assist untrained rescue personnel.

### SECTION III

The crew compartment doors are hinged and open outward. On several occasions it was noted that attempts to open the cabin doors in a similar manner were made. This could prove to be time consuming in the event of a post-crash fire if the rescue personnel were not familiar with the direction of operation. This is discussed more fully in Appendix A. The interior is placarded with a direction arrow and the word "Pull" for the benefit of the occupants. The entrances and exits in HU-1 and the HU-1A are considered adequate for rapid evacuation. However, clearly readable door operating instructions should be placed on the exterior near the operating handle.

#### CONCLUSIONS

Based upon the foregoing evaluation of the main cabin, these conclusions are reached:

1. The troop seats are undesirable from a crash safety point of view;
2. The safety belts, in most cases, do not afford adequate restraint due to improper installation;
3. The tie-down and structural ability of the entire litter installation to withstand failure and structural collapse of the entire assembly does not appear to be compatible with anticipated survivable crash force conditions;
4. The number of exits are adequate although they cannot be jettisoned from either the interior or the exterior; and
5. The absence of exterior door operating instructions could increase the exposure time in the event of a post-crash fire.

#### RECOMMENDATIONS

To attain greater crash safety, it is recommended that:

1. The specification for the Army troop seat be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration;
2. The safety belts be attached to the cables provided in the helicopter in order to afford the occupant maximum restraint;

### SECTION III

3. The specifications for Army aircraft litter installation be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration; and
4. The main cabin door be placarded on the exterior as to the method and direction of operation in a manner that can be easily understood by untrained rescue personnel.

## COMPILATION OF CONCLUSIONS

Conclusions set forth in the various sections of this report are recapitulated here according to section headings.

### BASIC AIRFRAME (Section I)

1. The skid-type landing gear incorporates energy absorption capabilities;
2. The location of the fuel tanks offers crash injury protection from a post-crash fire;
3. The exits in the aircraft are adequate;
4. The vertical side supports will buckle or collapse and the aft roof support will fail under crash forces well below survivable limits. This results in the roof impinging upon the occupiable crew and cabin areas with serious effects;
5. The tie-down strength of both the transmission and the engine is inadequate. Failure at crash force levels well below survivable limits may result in the transmission being projected through the aft bulkhead into the occupiable cabin area;
6. The absence of operating instructions on the exterior of cabin doors could increase the exposure time on the occupants in the event of a post-crash fire; and
7. The absence of exterior markings in regard to the location of the hand fire extinguisher also could increase the exposure time in the event of a post-crash fire.

### CREW COMPARTMENT (Section II)

Based upon the foregoing evaluation of the crew compartment, it is concluded that:

1. The sharp lower edges of the instrument panel could contribute to lower extremity injuries;
2. The seat back and the seat cushion provide adequate comfort and protection to the crew members;

3. The safety belt does not incorporate a self-aligning omnidirectional anchorage;
4. The seat belt is attached to the seat instead of to primary structure and, therefore, the safety belt does not provide maximum possible protection;
5. The inertia reel is attached to seat instead of to primary structure and, therefore, the shoulder harness does not provide the maximum possible protection;
6. The shoulder harness guide on the crew seats is too wide;
7. The tie-down requirements for the pilot and copilot seats are inadequate;
8. The tie-down requirement for the Crew Chief/Medical Attendant seat is inadequate; and
9. The absence of exterior emergency releases could increase the exposure time in the event of a post-crash fire.

#### MAIN CABIN (Section III)

Based upon the foregoing evaluation of the main cabin, these conclusions are reached.

1. The troop seats are undesirable from a crash safety point of view;
2. The safety belts, in most cases, do not afford adequate restraint due to improper installation;
3. The tie-down and structural ability of the entire litter installation to withstand failure and structural collapse of the entire assembly does not appear to be compatible with anticipated survivable crash force conditions;
4. The number of exits are adequate although they cannot be jettisoned from either the interior or the exterior; and
5. The absence of exterior door operating instructions could increase the exposure time in the event of a post-crash fire.

## COMPILATIONS OF RECOMMENDATIONS

The recommendations set forth in this report are:

### BASIC AIRFRAME (Section I)

Based on the foregoing conclusions, the following recommendations are made:

1. The following elements should be redesigned to provide increased strength requirements compatible with survivable crash force magnitudes, directions, and time duration:
  - (a) vertical side supports;
  - (b) the aft roof support ; and
  - (c) transmission and engine installations, particularly the transmission.
2. The exterior of the main cabin doors should be placarded as to the method and direction of operation with letters large enough and with sufficient contrast to be easily recognized as an escape area by untrained rescue personnel; and
3. Exterior markings giving the location of the fire extinguisher should be added.

### CREW COMPARTMENT (Section II)

Based upon the evaluation of the crew compartment, it is recommended that:

1. The lower edges of the instrument panel be padded with an energy absorbing material;
2. The present safety belt anchorage be changed to a self-aligning omni-directional attachment;
3. The seat belt be attached to primary structure;
4. The inertia reel on the pilot and copilot seats be attached to primary structure;
5. The shoulder harness guide be reduced to a minimum width;

6. The Military Specification dealing with the tie-down requirement for the pilot's and copilot's seats be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration;
7. The Military Specification dealing with the tie-down requirement for the Crew Chief/Medical Attendant's seat be revised to provide strength requirements compatible for survivable crash force magnitudes, directions, and time duration; and
8. Equip both pilot and copilot cockpit doors with outside emergency door mounting releases to permit jettisoning of doors regardless of distortion or damage to the doors and/or adjacent cabin structure.

#### MAIN CABIN (Section III)

To attain greater crash safety, it is recommended that:

1. The specification for the Army troop seat be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration;
2. The safety belts be attached to the cables provided in the helicopter in order to afford the occupant maximum restraint;
3. The specifications for Army aircraft litter installation be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration; and
4. The main cabin door be placarded on the exterior as to the method and direction of operation in a manner that can be easily understood by untrained rescue personnel.

APPENDIX A  
SUMMARY OF CRASH SAFETY CRITERIA



## SUMMARY OF CRASH SAFETY CRITERIA

In its efforts to determine the crash survival aspects of aircraft accidents AvCIR, a Division of the Flight Safety Foundation, is guided by certain criteria which it considers fundamental for the crash protection of aircraft occupants. The same criteria are also used to evaluate the crash safety features of mock-ups and prototypes.

## CRASHWORTHINESS

Crashworthiness may be defined as the ability of basic aircraft structure to provide protection to occupants during survivable impact conditions. Impact conditions are considered survivable in that part of the cockpit/cabin area where the crash forces are within the limits of human tolerance (with minimal or no injury)\* and where surrounding structure remains reasonably intact.

Lack of crashworthiness, generally, indicates that the basic aircraft structure, seen as a protective container, is subject to extensive inward collapse thereby affecting the "inhabitability" of this area. Typical in this respect are (1) the rearward movement of the engine in single engine aircraft; (2) the downward displacement of transmissions and other heavy components in helicopters; (3) the upward collapse of lower structures into the cockpit/cabin area. This deformation or collapse of the occupiable area may result in crushing type injuries or trapping of the occupants.

When evaluating the crashworthiness of basic aircraft structure, stress is placed upon the expected behavior of this structure during a survivable type impact. Attention is also given to anticipated dynamic response under the most probable conditions of impact angle and aircraft attitude, based upon accumulated past experience. This facilitates an appraisal of the possibility of displacement of certain heavy components into the occupiable area as a result of inertia forces.

## TIE-DOWN CHAIN

Although a crashworthy structure provides primary protection during a crash deceleration, injuries may still occur when occupants are allowed to come into forceful contact with their environment or to be struck by loose objects thrown through the occupiable area. The restraint system used to prevent occupants, cargo and components from being thrown loose within the aircraft is commonly referred to as the tie-down chain. The occupant's tie-down chain consists of: seat belt, seat belt anchorage, shoulder harness and anchorage, seat structure, seat anchorages and floor. Failure of any link in this chain results in a higher degree of exposure to injury.

Accident statistics indicate that the site of most serious and frequent injury in general aviation accidents is the head. In most cases, this is due to lack of restraint, allowing the head to gain

momentum during impact and to strike objects in its path with a force exceeding that of the overall crash deceleration. This is especially true in the case of cockpit occupants who face the instrument panel, control wheel and many other injurious environmental structures. Considering these factors, it is practically impossible to avoid contact injuries during crash deceleration when such occupants are not restrained by a properly installed and properly used shoulder harness of adequate strength in combination with a seat belt.

Although seat structure and anchorages meet static strength tie-down requirements, failures frequently occur as a result of dynamic loads imposed by the occupants on seat belts and shoulder harnesses when these are anchored to the seats instead of primary structure. This type of crash force amplification should be taken into consideration when evaluating the dynamic strength of the occupant tie-down chain. Inadequately or improperly secured aircraft equipment and components in the occupiable area also have an injury potential during crash decelerations. Therefore, the tie-down and stowage of such items as luggage, cargo, radio equipment, fire extinguishers and tool boxes requires careful consideration.

## OCCUPANTS' ENVIRONMENT

Accident experience has shown that under many impact conditions occupants who are reasonably restrained within a crashworthy structure may still receive injuries through forceful contact with injurious environmental structures, components, etc. (This is particularly true when shoulder harness is not used.) The freedom of movement of the occupant's body during a crash deceleration is governed by the type of restraint system installed and the manner in which it is used. Generally, it can be stated, however, that injuries resulting from the flailing action of the occupant's body show a peripheral trend; that is, the areas farthest away from the seat belt receive most of the injuries (head and lower extremities).

To preclude the probability of injury through striking injurious environment, the limitations of the restraint system should be used as a guide for the extent to which the occupant's environment should be made harmless. The injury potential of all objects and structure within striking range, omni-directionally, can be reduced to a minimum by such measures as elimination of sharp surfaces, safety-type control wheels, breakaway features in instrument panels, use of ductile or energy-absorbing material wherever possible.

\*Approximately 40G transverse to the spine, 25G parallel to the spine (positive G), 15G parallel to the spine (negative G) with due consideration for peak magnitude, duration, rate of onset, and method of body restraint. J.P. Stapp, Human Exposure to Linear Deceleration, Part 2. The Forward-Facing Position and the Development of a Crash Harness. WADC, Wright-Patterson AFB, Ohio, Dec. 1951. A.F. Technical Report No. 5915, Part 2.

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## APPENDIX A

### TRANSMISSION OF CRASH FORCE

Another independent injury-producing factor presents itself in the fact that crash forces may be transmitted or even magnified through rigid aircraft structures. This is usually associated with "bottoming out" on structures incapable of absorbing or reducing crash force. Although crash force in most accidents is applied in a direction oblique to the occupant's spine, it is customary to resolve vertical and horizontal components of the crash force resultant and relate these to the human G-force tolerance levels, either parallel or transverse to the spine. A normally seated person, when effectively restrained by a seat belt and shoulder harness, can tolerate (with minimal or no injury) approximately 40 G transverse to the spine, 25 G parallel to the spine in the foot-to-head direction (positive G), 15 G parallel to the spine in the head-to-foot direction (negative G).

Injuries attributed solely to transverse G will seldom be encountered in aircraft accidents, because collapse of structure and/or failure of the restraint system will most likely occur before the limit of transverse G tolerance (40 G) is reached. This is an undesirable situation. Although operational and economic considerations impose limits on the overall fuselage strength, the occupant tie-down chain should be more compatible in strength with tolerance levels of the body.

Accident experience has shown that injuries directly attributed to the transmission or magnification of crash force are usually associated with predominantly vertical impacts. Vertebral injuries are most often associated with vertical crash force application.

The seat, as the occupant's supporting structure, and the underlying floor structure are the media through which vertical forces are usually transmitted to the occupant. The dynamic response of these media during an impact determines the manner in which the forces acting on the aircraft structure can be modified before reaching the occupant. An extremely rigid structure, which normally is not found in aircraft, would transmit the forces without modification. An elastic structure, which has energy-storing properties, may modify the magnitude and other characteristics of decelerative force to the extent that amplification takes place. For example, a foam rubber cushion (which does not offer an appreciable resistance to compression) allows an occupant to "bottom out" against rigid seat and seat pan structures during a vertical impact. A more desirable situation would be that in which the structure between the occupant and the point of impact had high energy-absorbing characteristics. This may be achieved by the use of structure which collapses progressively without failing suddenly. This ideal form of crash energy absorption results in attenuation of the crash forces transmitted to the occupant. It is one of the basic methods for the incorporation of occupant protection in aircraft design.

### POST-CRASH FACTORS

Although a distinction could be made between the prevention of injuries sustained in the dynamic phase of the impact and those sustained in the post-crash events, it is felt that the overall crash survival concept does not allow this distinction. Past experience has shown that accidents involving only very minor impact forces can become catastrophes as a result of post-crash factors.

One of the greatest hazards in an otherwise survivable accident is the possibility of a post-crash fire. These fires, normally, are of a sudden nature and may severely restrict the time available for evacuation. According to a NACA study (Technical Note 2996), not more than 50 seconds may be available for escape in all but the most severe fires, although in some cases passengers must move away from areas of burned-through fuselage in as few as 7-1/2 seconds. This time element becomes even more critical when occupants are handicapped by such factors as disabling injuries, stunned condition, unfamiliarity with the seat belt release or the operation of the emergency exits, being trapped, and panic.

Control of post-crash fires, to some extent, is governed by design (location of fuel cells and fuel lines in relation to electrical and mechanical ignition sources; resistance of fuel system components against rupture under conditions of moderate crash forces or distortion). Other preventive measures include location of fire extinguishers at strategic points and automatic emergency or impact-operated fire extinguishing systems.

In the event of a post-crash fire or a ditching, the ability of all occupants to timely evacuate the aircraft probably becomes the most important survival factor. The evacuation time is a function of the number, location and adequacy of the normal and emergency exits.\* The location and emergency operation of normal and emergency exits should be obvious even to the non-experienced passenger. Hand or impact-operated emergency lights can be of vital importance during evacuation in conditions of darkness or subdued light.

\* HIAD (the military Handbook of Instructions for Aircraft Designers) requires "a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching, in 30 seconds by trained personnel representing the crew and all passengers."

OCT 15 '60

APPENDIX B

DESCRIPTION OF THE ACCIDENTS AND SEATING CHARTS

ACCIDENT "A"

HU-1A, East St. Louis, Illinois, 21 October 1959

A U. S. Army HU-1A Bell helicopter crashed while on a demonstration flight at Parks Air College Airfield, East St. Louis, Illinois, at 1055 on 21 October 1959.

The helicopter had completed a high-speed run parallel to and in front of the spectators when the pilot initiated a cyclic climb to approximately 500 feet above the terrain to prepare for an autorotative descent. Upon arriving at the desired altitude with a velocity of 30 to 40 knots, he made an 180-degree turn, reduced power, lowered the nose of the aircraft, and entered autorotation. Immediately after entering the maneuver, the pilot noted an unusually high rate of descent, at a point estimated to have been 200 feet above the terrain. He leveled the aircraft, applied full power and collective pitch, but was unable to decrease the high rate of vertical descent. He continued application of power and pitch, and just prior to the crash, succeeded in partially reducing the high "sink" rate. At impact the tail boom began shearing loose and tore completely free as the aircraft rebounded into the air. The aircraft struck the ground two more times, finally coming to rest in an inverted position approximately 420 feet from the point of initial impact. During this sequence the engine tore free from its mounts and rolled far to the right of the crash path. Cargo and cabin doors were torn free. The main transmission, mast, and rotor assembly tore free during the rolling of the aircraft near the end of the crash path. The roof failed in compression, collapsing against the seat backs of the pilot and crew chief's seats. (It is reasonable to assume that the vertical side supports failed at initial impact. This is substantiated by the four other accidents that did not become inverted.) The forward deceleration was approximately 3.9G; the vertical load sustained was approximately 9.8G upon impact.



Over-all view of the East St. Louis, Illinois accident

# APPENDIX B

## ACCIDENT "A"

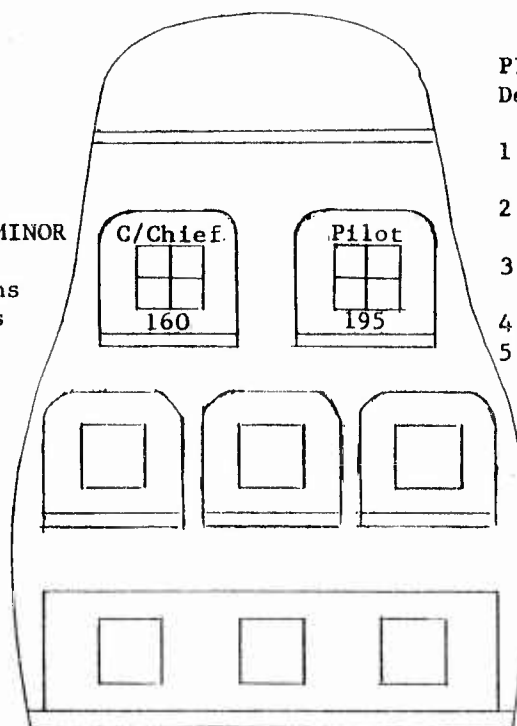
HU-1A EAST ST. LOUIS, ILLINOIS

21 OCTOBER 1959

SEATING ARRANGEMENT - INJURY CHART - SEAT FAILURE  
(OCCUPANTS' WEIGHT NOTED ON THEIR RESPECTIVE SEATS)

CREW CHIEF  
Degree of Injury-MINOR

1. Minor contusions and lacerations of head.



PILOT  
Degree of Injury-SERIOUS

1. Two 1" lacerations, right cheek.
2. Contusions, posterior lower arms.
3. Compression fracture L-1.
4. Fracture, 7th rib.
5. Linear vertical fracture of sacrum, sacroiliac joint.

☐ VACANT

☒ OCCUPIED-SEAT INTACT

ACCIDENT "B"

HU-1, Fort Rucker, Alabama, 4 March 1960

A U. S. Army HU-1 Bell helicopter crashed while on practice flight 3 miles north of Hanchey AAF, Dale County, Alabama, at 1150 on 4 March 1960.

During a climbing right turn with approximately 60 knots indicated air speed and at about 250 feet above the ground, the pilot thought he smelled something burning. He reached up with his left hand to the overhead panel and turned off the aircraft heater, at the same time looking up to make sure he had the right switch. As a normal reaction to the outstretching of his left arm, he involuntarily applied a small amount of right forward cyclic, not realizing it because of the servo flight control system and the absence of force trim. This put the aircraft in a nose low attitude, increasing the air speed and allowing a rate of descent to build up to approximately 1,300 feet per minute. It also turned the aircraft downwind and picked up a 12-knot tail wind. By the time the pilot got his attention back and realized the attitude the aircraft was in, he was descending rapidly into a patch of trees which he reported were only about 50 feet away when he first saw them. His ground speed was in the neighborhood of 95 knots and with the rate of descent near 1,300 feet per minute, the aircraft had no time to respond to his control before hitting the trees and the ground. Just prior to ground contact the main rotor blade wrapped around an oak tree and pulled the transmission free of the aircraft. The aircraft continued on, striking the ground, bounced, and came to rest 20 feet from initial contact. The decelerative forces in this accident were estimated to be in excess of 14G's.



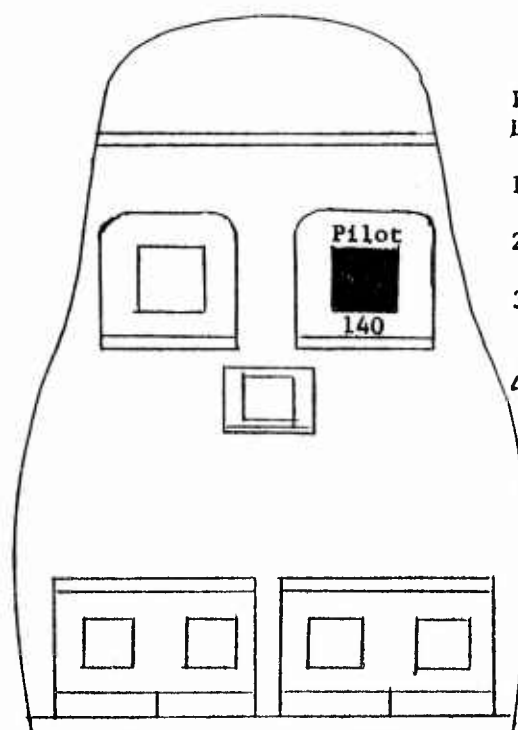
The HU-1 accident, Fort Rucker, 4 March 1960

APPENDIX B

ACCIDENT "B"

HU-1 FORT RUCKER, ALABAMA  
4 MARCH 1960

SEATING ARRANGEMENT - INJURY CHART - SEAT FAILURE  
(OCCUPANTS' WEIGHT NOTED ON THEIR RESPECTIVE SEATS)



PILOT  
Degree of Injury - SEVERE

1. Avulsion of scalp-half moon shaped 3" x 2".
2. Bilateral lacerations 1" (infra-orbital)
3. Simple fracture of thumb & little finger, left hand.
4. Simple fracture of fibula, right leg.

 VACANT

 OCCUPIED-SEAT FAILED

ACCIDENT "C"

HU-1A, Fort Carson, Colorado, 9 June 1960

A U. S. Army HU-1A Bell helicopter transporting personnel from Butts AAF, Fort Carson, Colorado, crashed during an attempted landing at 1105 on 9 June 1960. The intended landing site was the combat field range at Fort Carson Military Reservation (elevation: 6,560 feet M. S. L.) approximately nine miles southwest of Butts AAF, Fort Carson, Colorado.

During approach to an intended landing site, the pilot observed an obstruction and initiated a climbing turn to the right. At approximately 270° of the turn and 300 feet of altitude, a partial power failure occurred. The pilot immediately actuated the increase power switch; power increased momentarily and then decreased between partial and full loss of power. The pilot lowered the nose of the aircraft, entered autorotation, and committed the aircraft to a forced landing. Upon entry into autorotation, the pilot noted a very steep angular approach and an unusually high rate of descent. Just prior to the crash, he succeeded in reducing this high "sink-rate" by one-half, to approximately 1,500 feet per minute, and then executed a full flare. During the full flare the main rotor blades contacted a large pine tree causing sudden stoppage of the rotor system as the aircraft forcibly contacted the ground. Due to the sudden stoppage of the rotors, transmission mounts failed, allowing the transmission and its components to penetrate the aft bulkhead into the occupiable area. The decelerative forces in this accident were computed to be approximately 13G.



Side view of the Fort Carson accident.



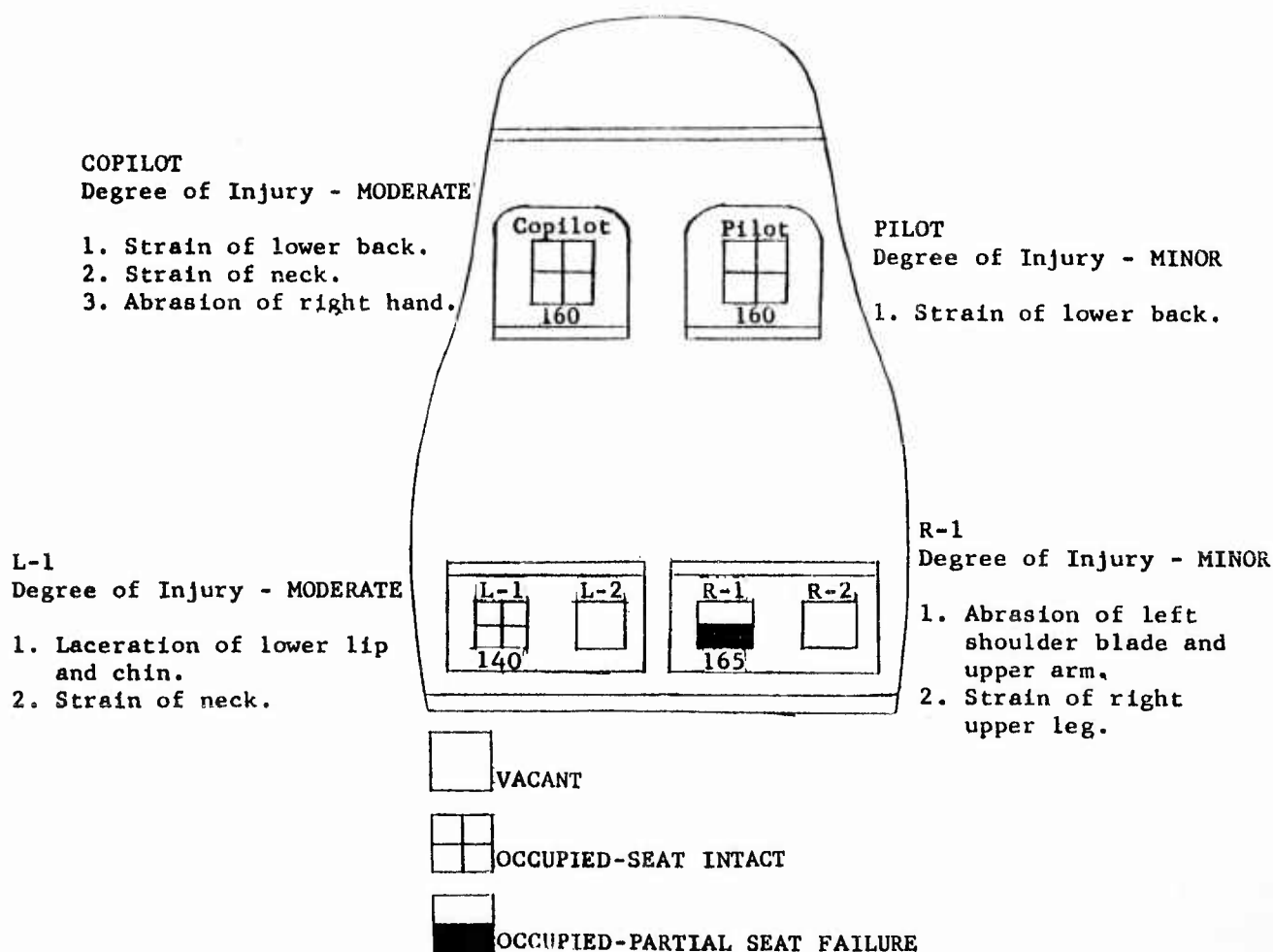
# APPENDIX B

## ACCIDENT "C"

HU-1A FORT CARSON, COLORADO

9 JUNE 1960

SEATING ARRANGEMENT - INJURY CHART - SEAT FAILURE  
(OCCUPANTS' WEIGHT NOTED ON THEIR RESPECTIVE SEATS)



ACCIDENT "D"

HU-1A, Fort Bragg, North Carolina, 20 August 1960

A U. S. Army HU-1A Bell helicopter crashed while participating in a field exercise on the Fort Bragg Military Reservation at 1455 hours on 20 August 1960.

The pilot, having entered the downwind leg for the intended landing site, felt the aircraft settle and immediately noticed a drop in rotor R. P. M. While at approximately 200 feet, he immediately lowered the nose to maintain rotor R. P. M. and committed the aircraft to a forced landing. The immediate area consisted of 50 to 60 feet high pine trees. As the aircraft entered the wooded area, a nose high, full flare was initiated prior to the main rotor severing a 10-inch diameter tree approximately 35 feet above the ground. From this point the aircraft settled in a tail low attitude until striking the ground. During this latter sequence the cabin area just aft of the pilot's seat on the right side was impaled on a stump approximately 10 inches high which penetrated into the inhabitable area. Accurate measurements were unobtainable due to a continuous rain which eliminated most of the gouge marks although evidence indicates the vertical load sustained was approximately 14G while the longitudinal force was approximately 4G.



Side view, HU-1A, Fort Bragg, North  
Carolina, 20 August 1960

# APPENDIX B

## ACCIDENT "D"

HU-1A FORT BRAGG, NORTH CAROLINA  
20 AUGUST 1960

SEATING ARRANGEMENT - INJURY CHART - SEAT FAILURE  
(OCCUPANTS' WEIGHT NOTED ON THEIR RESPECTIVE SEATS)

### COPILOT

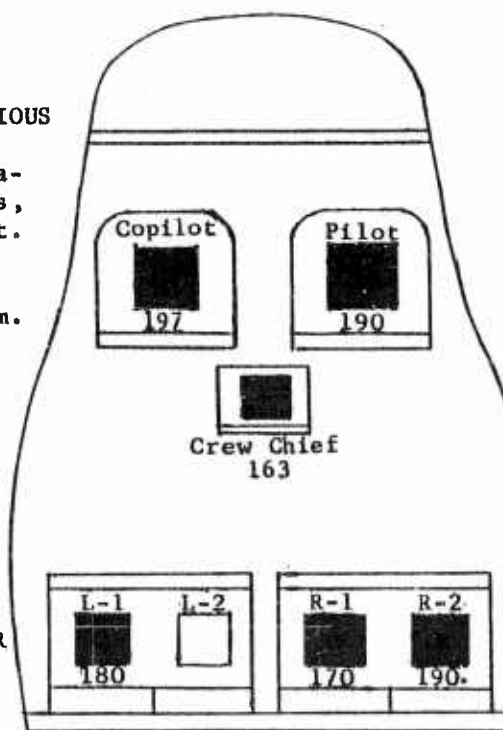
Degree of Injury - SERIOUS

1. Abrasions and lacerations of extremities, lower back and chest.
2. Depressed xiphoid.
3. Hematoma of left buttock into scrotum.

### L-1

Degree of Injury - MINOR

1. Contusion of left shoulder blade.



☐ VACANT

☒ OCCUPIED - SEAT FAILED

### PILOT

Degree of Injury - SERIOUS

1. Compression fracture of T 11 & 12.
2. Fracture, base of 1st metacarpal.
3. Abrasions and contusions of face and extremities.

### CREW CHIEF

Degree of Injury - SEVERE

1. Mild concussion.
2. Numerous facial and scalp lacerations.
3. Lacerations of right hand and leg.
4. Comminuted fracture of right leg.

### R-1

Degree of Injury - CRITICAL

1. Severe laceration of scalp.
2. Depressed skull fracture occipital area.
3. Partial maceration of brain, occipital area.

### R-2

Degree of Injury - SERIOUS

1. Facial and neck abrasions.
2. Tenderness of upper abdomen.
3. Tenderness of lower back.
4. Contusion of right buttock.
5. Internal injuries.

ACCIDENT "E"

HU-1A, Fort Rucker, Alabama, 26 August 1960

A U. S. Army HU-1A Bell helicopter crashed at 0650 hours, 26 August 1960 while on a service mission.

While in level flight at cruise power, the crew heard loud banging noises followed by moderate oscillation of the aircraft through all axes. Upon increasing collective pitch and power the helicopter started to yaw. The pitch control was immediately reduced to minimum and the pilot checked his anti-torque pedals. When no response was forthcoming, he then realized he had lost his tail rotor. He turned toward the runway which also placed the clearest available area in his flight path. Yaw control could only be maintained with the pitch bottomed. The pilot, realizing he could not make the runway, elected to head for the clearest area available. When approaching touchdown, a flare was executed to reduce touchdown speed. As the speed was reduced, the yaw increased to the left. The aircraft hit the top of several oak trees moving forward and downward through the trees. The initial impact with the trees was about 50 feet above the ground. The aircraft stopped its forward motion after about 110 feet while 15 feet above the ground. At this point it rolled over on its left side and fell vertically, coming to rest on its left side. Accurate gouge marks were unobtainable although evidence indicates the load sustained in this accident was between 5G and 10G.



View of the HU-1A accident which occurred at Fort Rucker, Alabama, 26 August 1960.

APPENDIX B

ACCIDENT "E"

HU-1A FORT RUCKER, ALABAMA

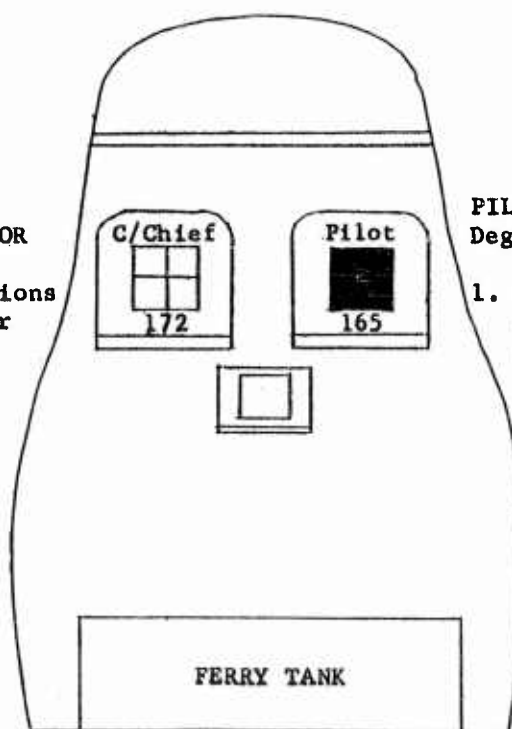
26 AUGUST 1960

SEATING ARRANGEMENT - INJURY CHART - SEAT FAILURE  
(OCCUPANTS' WEIGHT NOTED ON THEIR RESPECTIVE SEATS)

CREW CHIEF

Degree of Injury - MINOR

1. Lacerations, abrasions and contusions over entire body.



PILOT

Degree of Injury - MINOR

1. Lacerations, abrasions and contusions of extremities.



VACANT



OCCUPIED - NO FAILURE



OCCUPIED - SEAT FAILED

APPENDIX C  
SCALE OF INJURY USED BY AvCIR

## SCALE OF INJURY\* USED BY AVCIR

(Revised 4/60)

Degree of Injury	Classification and Description of Injury
None or Trivial	No Injury - Abrasions or scratches of a superficial nature.
Minor	"Minor" contusions, lacerations, abrasions in any area(s) of the body. Sprains, fractures, dislocations of fingers, toes, or nose. Dazed or slightly stunned. Mild concussion as evidenced by mild headache, with no loss of consciousness.
Moderate	"Moderate" contusions, lacerations, abrasions in any area(s) of the body. Sprains of the shoulders or principal articulations of the extremities. Uncomplicated, simple, or green-stick fractures of extremities, mandible and rib cage (excluding spine). Concussion as evidenced by loss of consciousness not exceeding 5 minutes, without evidence of other intracranial injury.
Severe (survival normally assured with prompt medical care and without complications)	Extensive lacerations without dangerous hemorrhage. Compound or comminuted fractures, or simple fractures with displacements. Dislocations of the arms, legs, shoulders or pelvisacral processes. Fractures of the facial bones excluding mandible. Severe sprains of the cervical spine. Fractures of transverse and/or spinous processes of the spine, without evidence of spinal cord damage. Fractures of vertebral bodies of the dorsal and/or lumbar spine, without evidence of spinal cord damage, or compression fractures of L-3-4-5 without evidence of damage to nervous system. Skull fracture without evidence of concussion or other intracranial injury. Concussion as evidenced by loss of consciousness of over 5 and up to 30 minutes, without evidence of other intracranial injury.
Serious (but survival probable)	Lacerations with dangerous hemorrhage. Fractures or dislocations of vertebral bodies of the cervical spine, without evidence of spinal cord damage. Compression fractures of vertebral bodies of dorsal spine and/or of L-1 and L-2 without evidence of spinal cord damage. Compression fractures of L-3-4-5 with

\*Based on observations during first 48 hours after injury and previously normal life expectancy.

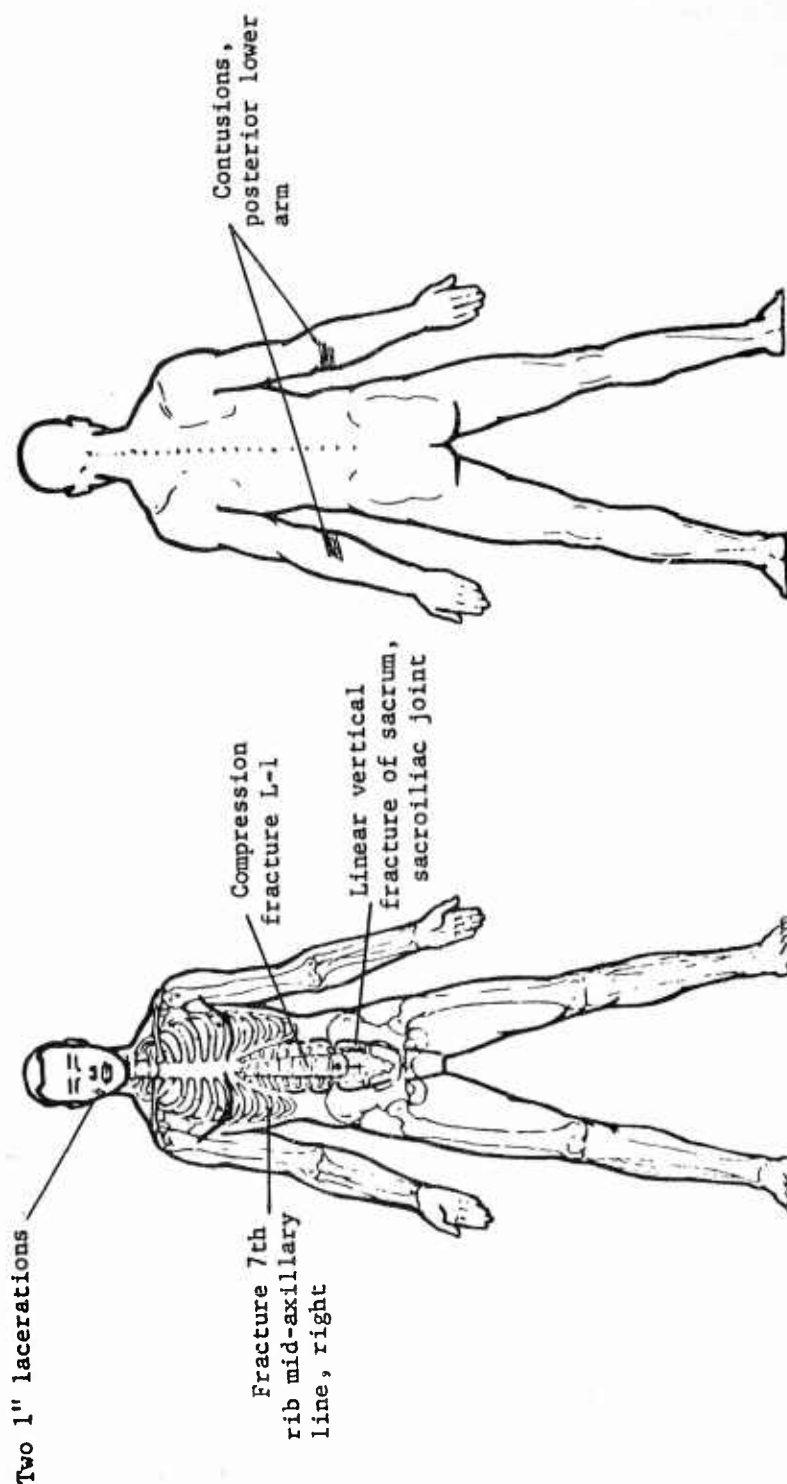
# APPENDIX C

Degree of Injury	Classification and Description of Injury
Serious (cont'd)	evidence of damage to nervous system. Crushing or multiple fractures of the extremities and/or of the chest. Indication of moderate intrathoracic or intra-abdominal injury. Skull fracture with concussion as evidenced by loss of consciousness up to 30 minutes. Concussion as evidenced by loss of consciousness of over 30 minutes to 2 hours, without evidence of other intracranial injury.
Critical (survival uncertain or doubtful. Includes fatal termination beyond 24 hrs.)	Evidence of dangerous intrathoracic or intra-abdominal injury. Fractures or dislocations of vertebral bodies of cervical spine with evidence of cord damage. Compression fractures of vertebral bodies of dorsal spine, and/or L-1, L-2, with evidence of spinal cord damage. Skull fracture with concussion as evidenced by loss of consciousness beyond 30 minutes. Concussion as evidenced by loss of consciousness beyond 2 hours. Evidence of critical intracranial injury.
Fatal within 24 hrs. of accident	Fatal lesions in single region of the body, with or without other injuries classed as Severe.
Fatal within 24 hrs. of accident	Fatal lesions in single region of the body, with other injuries classed as Serious or Critical.
Fatal	Fatal lesions in two regions of the body, with or without other injuries elsewhere.
Fatal	Fatal lesions in three or more regions of the body - up to and including demolition of the body.



APPENDIX D  
MEDICAL SUMMARIES

PILOT - RIGHT SEAT

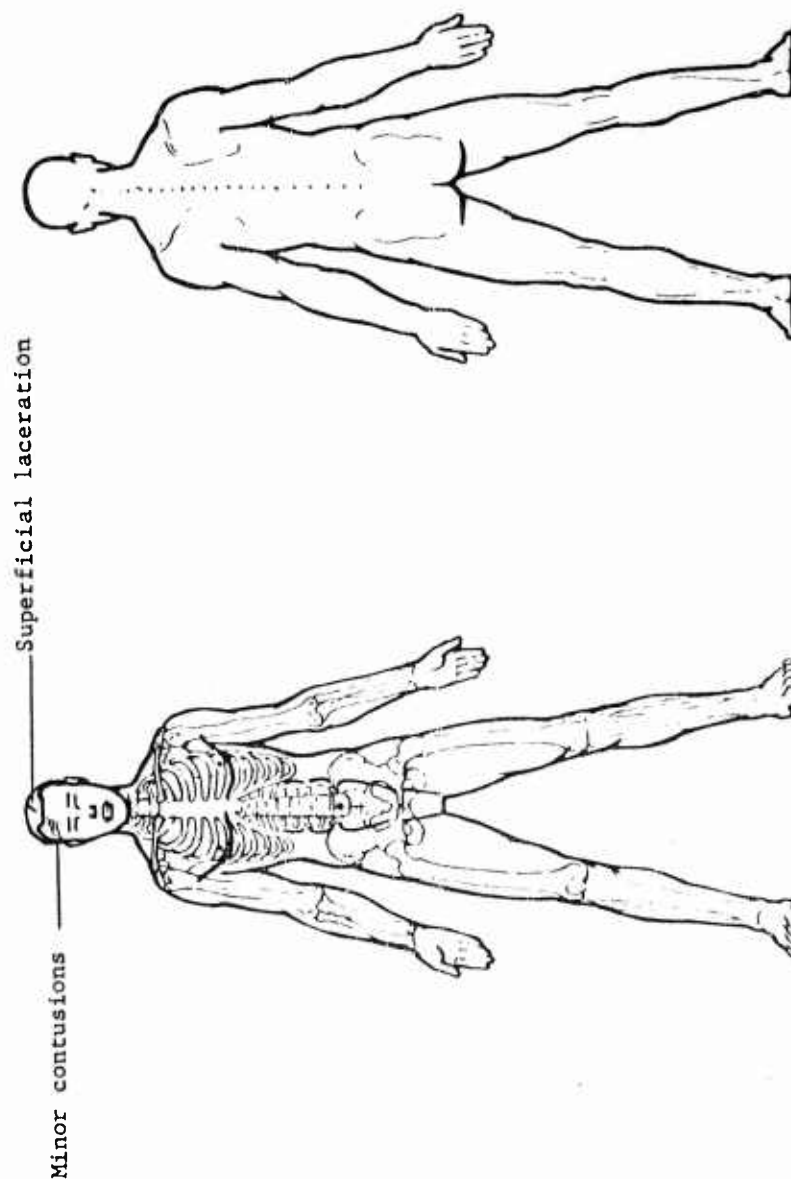


HU-1A - EAST ST. LOUIS, ILLINOIS

21 OCTOBER 1959

APPENDIX D

CREW CHIEF - LEFT SEAT



HU-1A - EAST ST. LOUIS, ILLINOIS

21 OCTOBER 1959

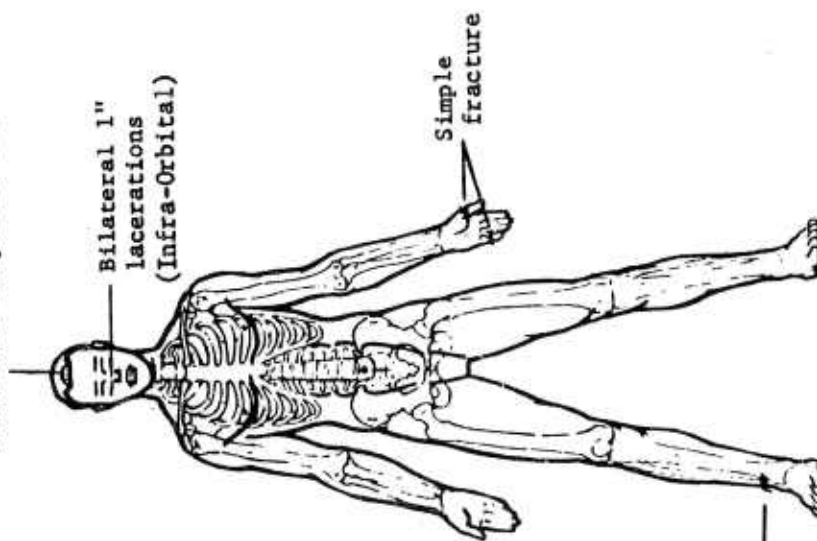
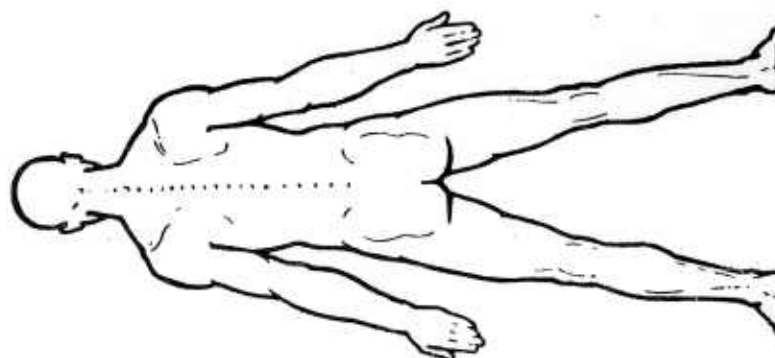
PILOT - RIGHT SEAT

Avulsion of scalp  
Half moon shaped 3" x 2"

Bilateral 1"  
lacerations  
(Infra-Orbital)

Simple  
fracture

Simple fracture

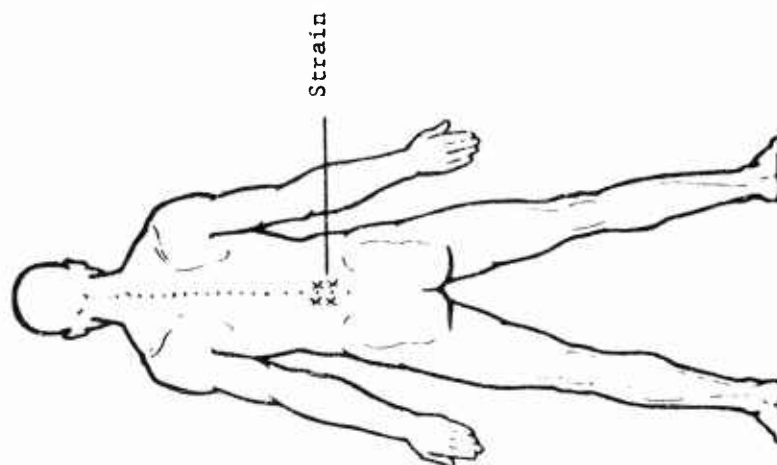
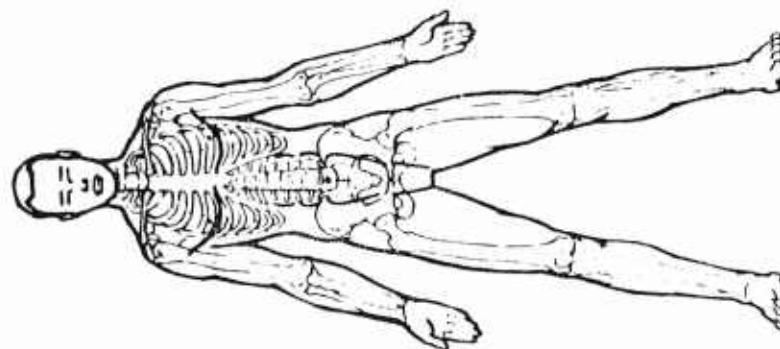


HU-LA - FORT RUCKER, ALABAMA

4 MARCH 1960

APPENDIX D

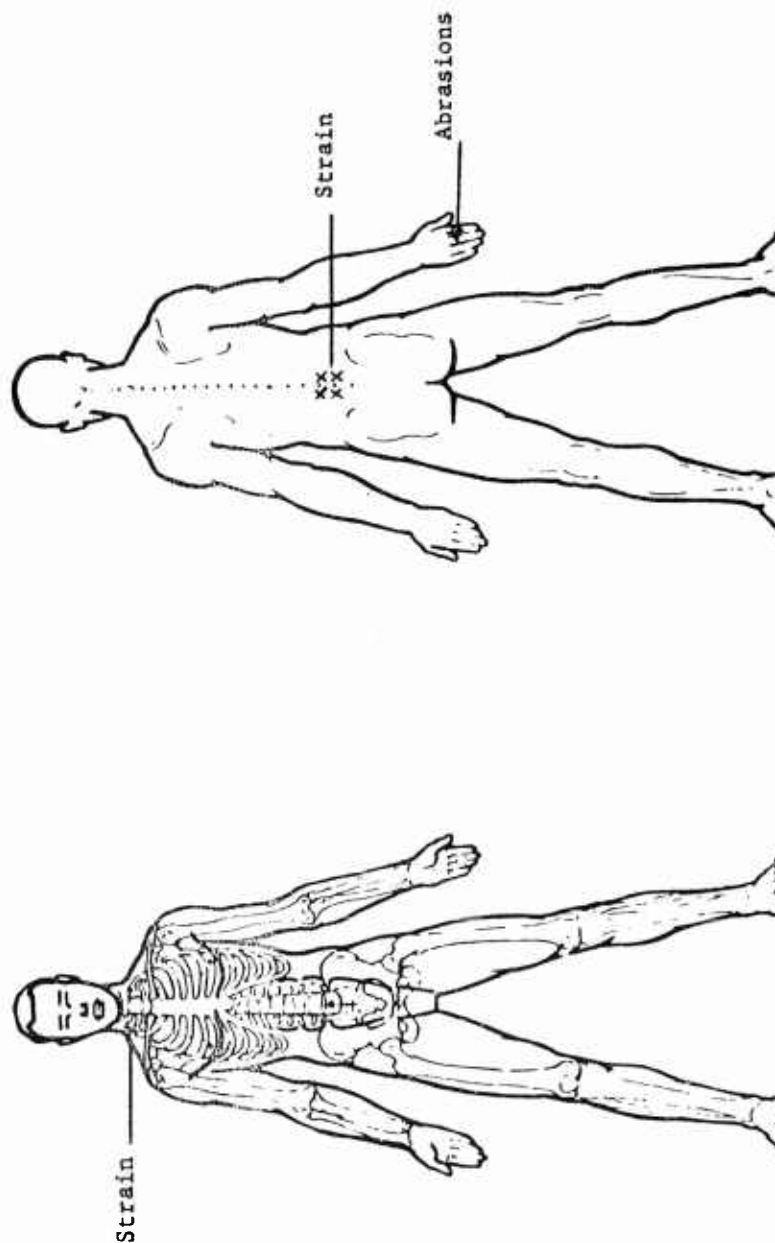
PILOT - RIGHT SEAT



HU-1A - FORT CARSON, COLORADO

9 JUNE 1960

CO-PILOT - LEFT SEAT

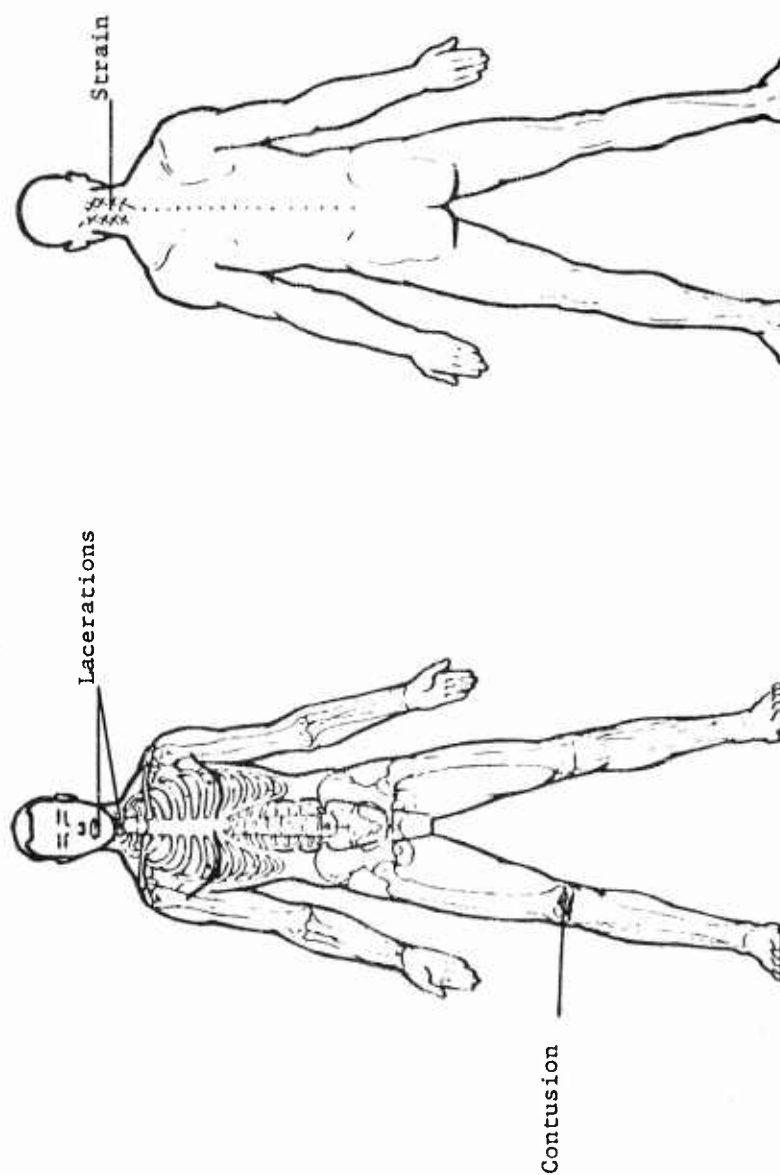


HU-1A - FORT CARSON, COLORADO

9 JUNE 1960

APPENDIX D

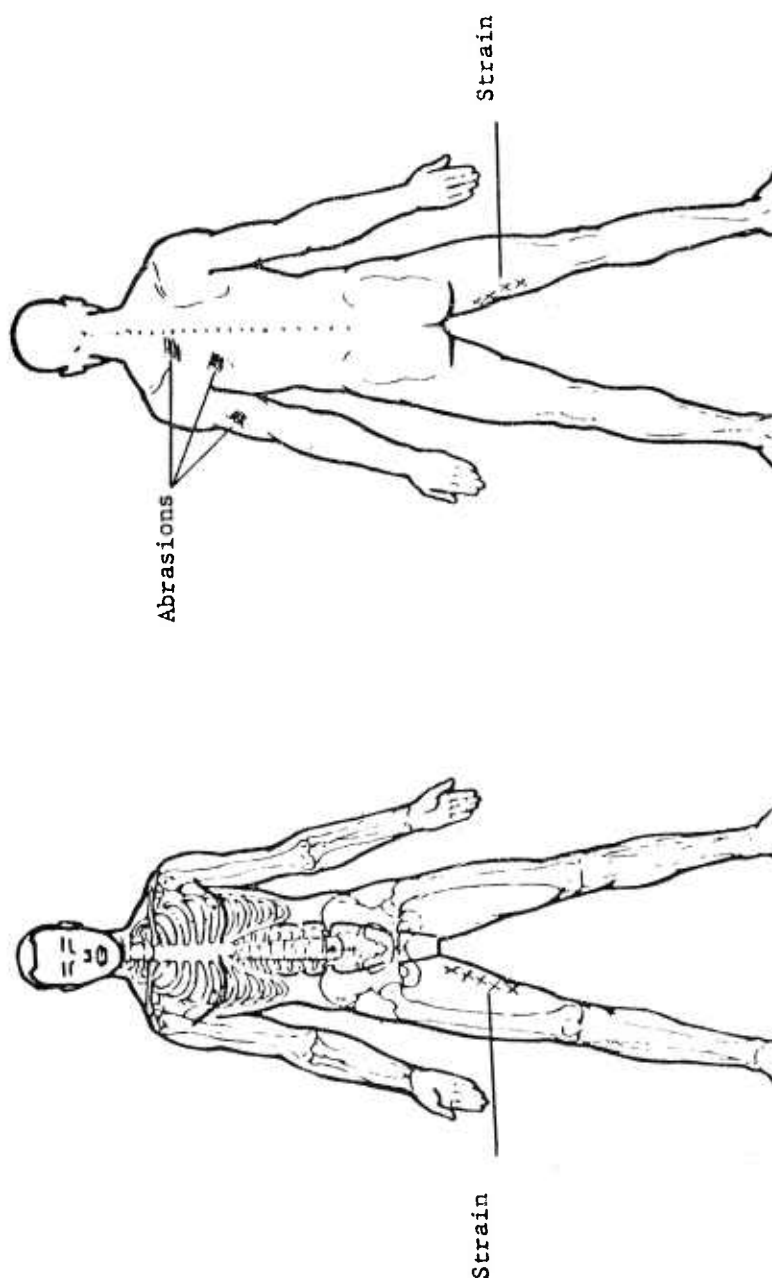
PASSENGER - L-1



HU-1A - FORT CARSON, COLORADO

9 JUNE 1960

PASSENGER - R-1



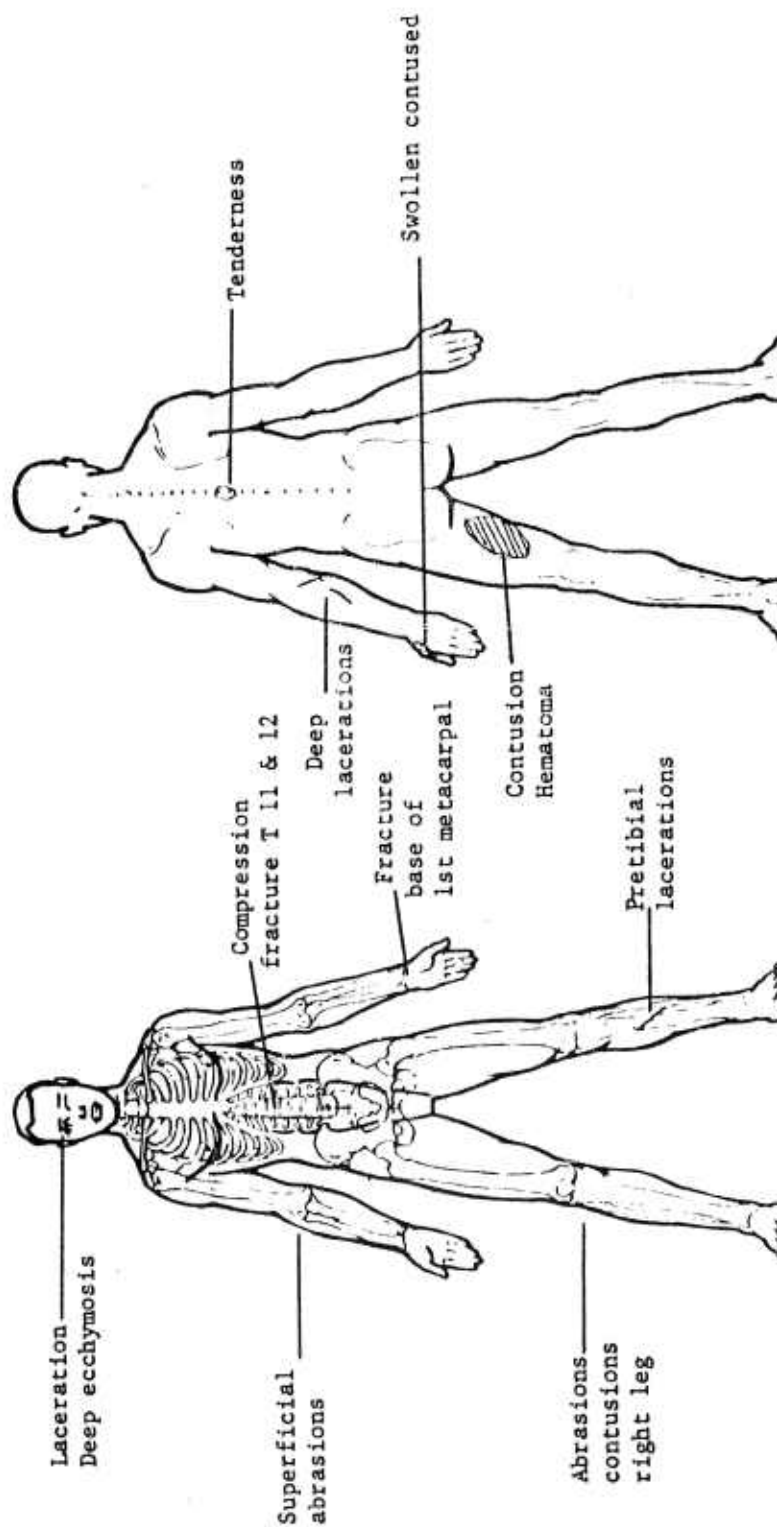
HU-1A - FORT CARSON, COLORADO

9 JUNE 1960



# APPENDIX D

## PILOT - RIGHT SEAT

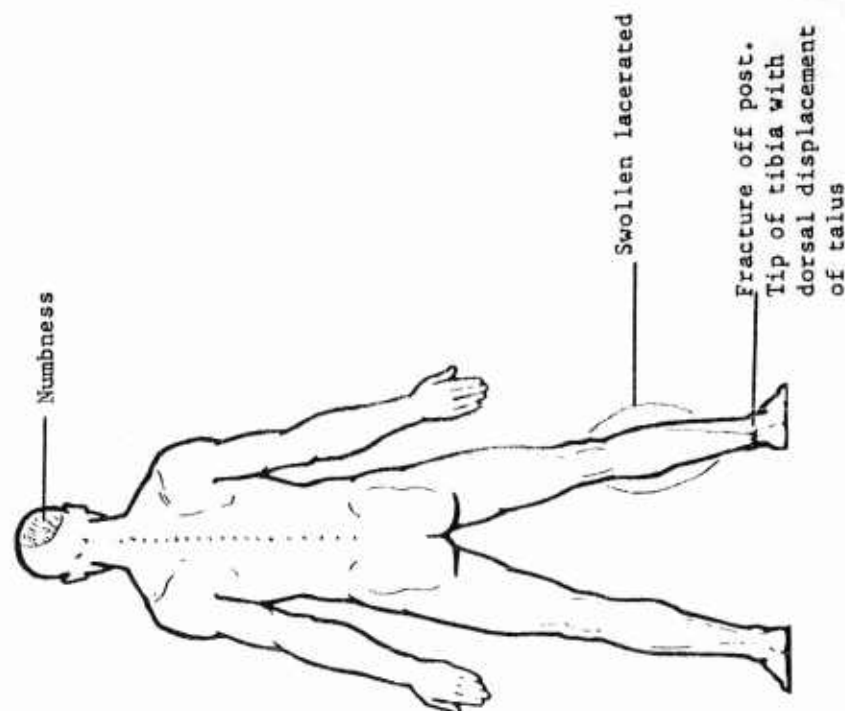
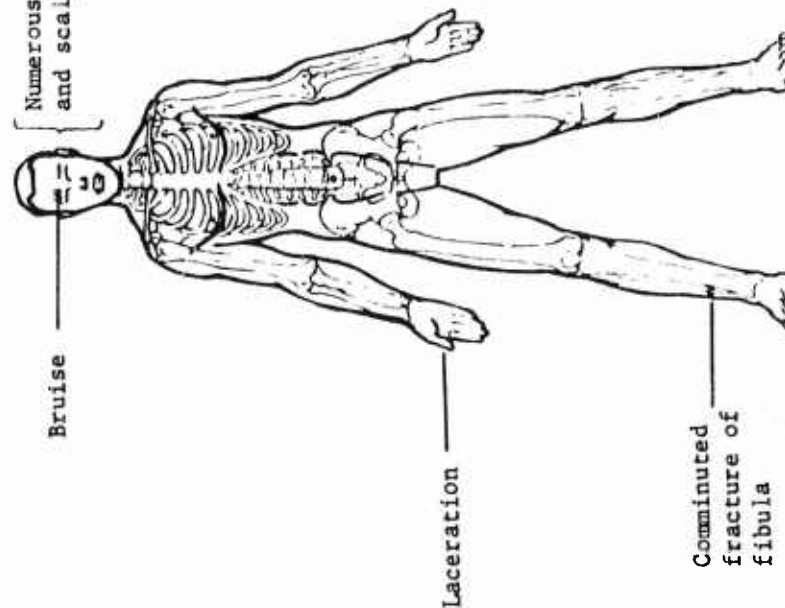


HU-1A - FORT BRAGG, NORTH CAROLINA

20 AUGUST 1960

CREW CHIEF - CENTER SEAT

Mild Concussion



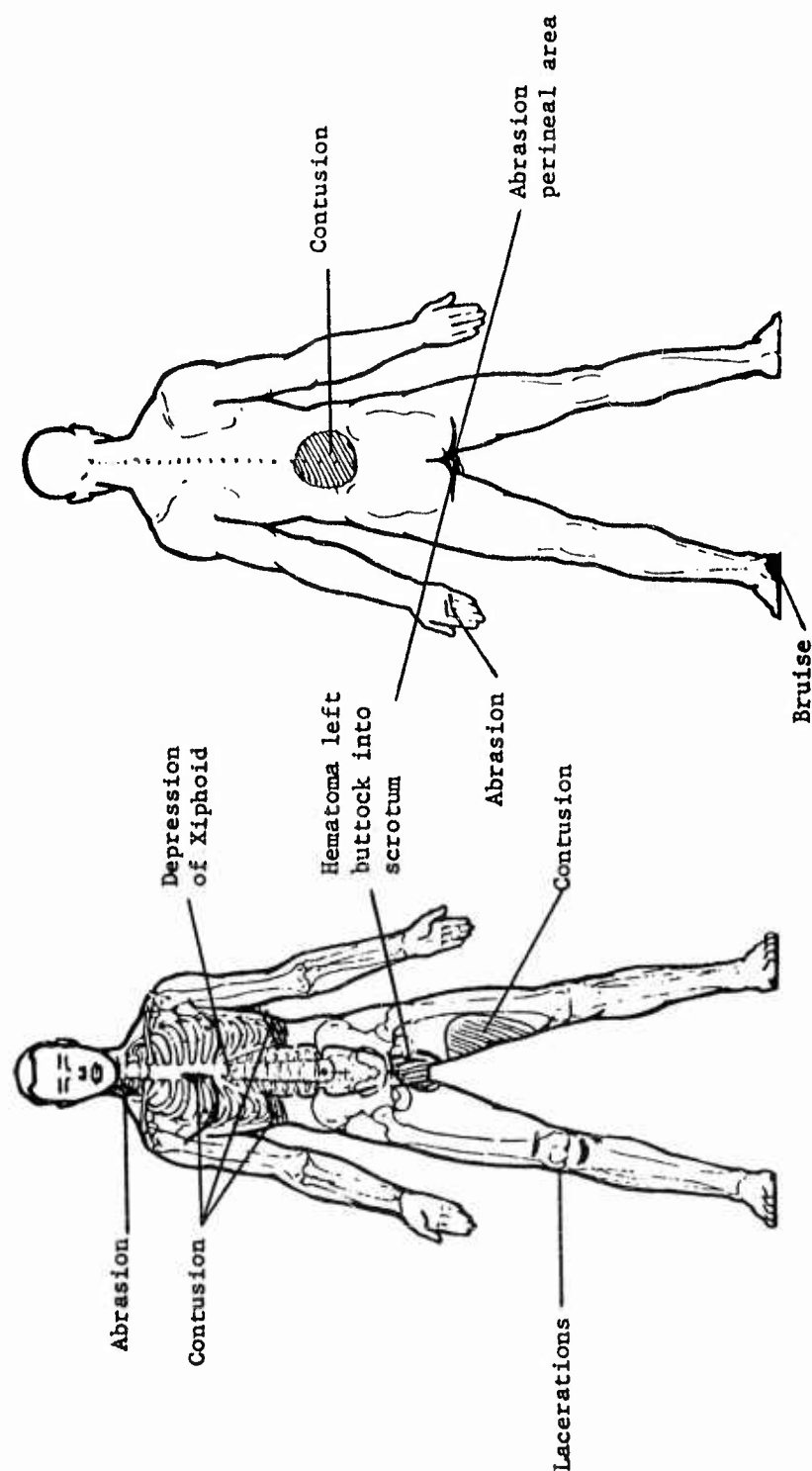
APPENDIX D

HU-1A - FORT BRAGG, NORTH CAROLINA

20 AUGUST 1960

# APPENDIX D

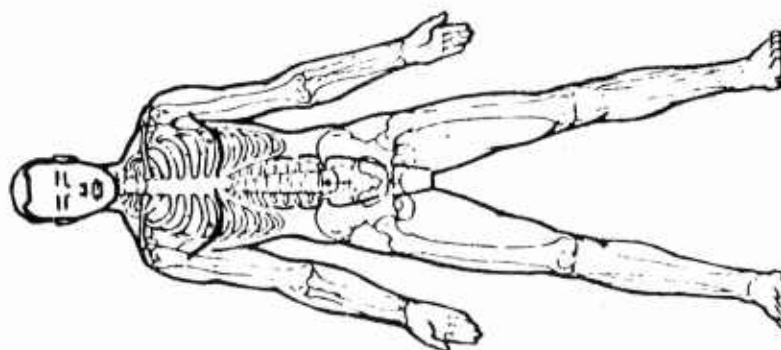
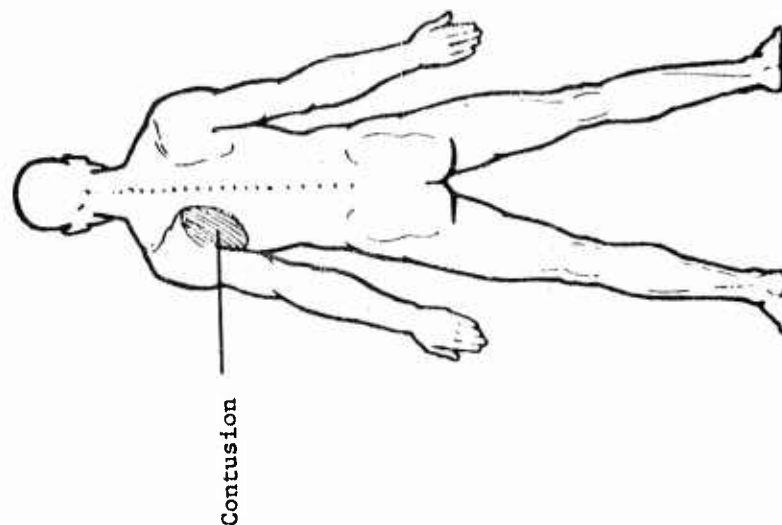
## PASSENGER - LEFT SEAT



HU-1A - FORT BRAGG, NORTH CAROLINA

20 AUGUST 1960

PASSENGER - R-1

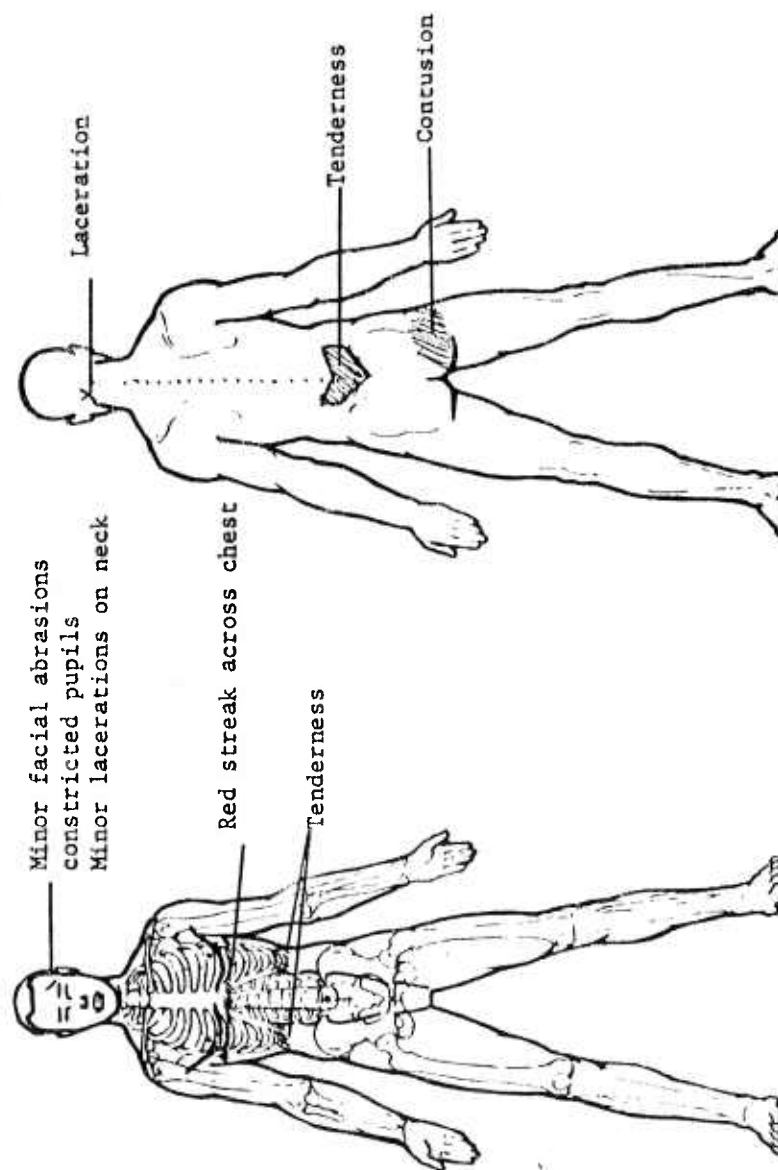


HU-1A - FORT BRAGG, NORTH CAROLINA

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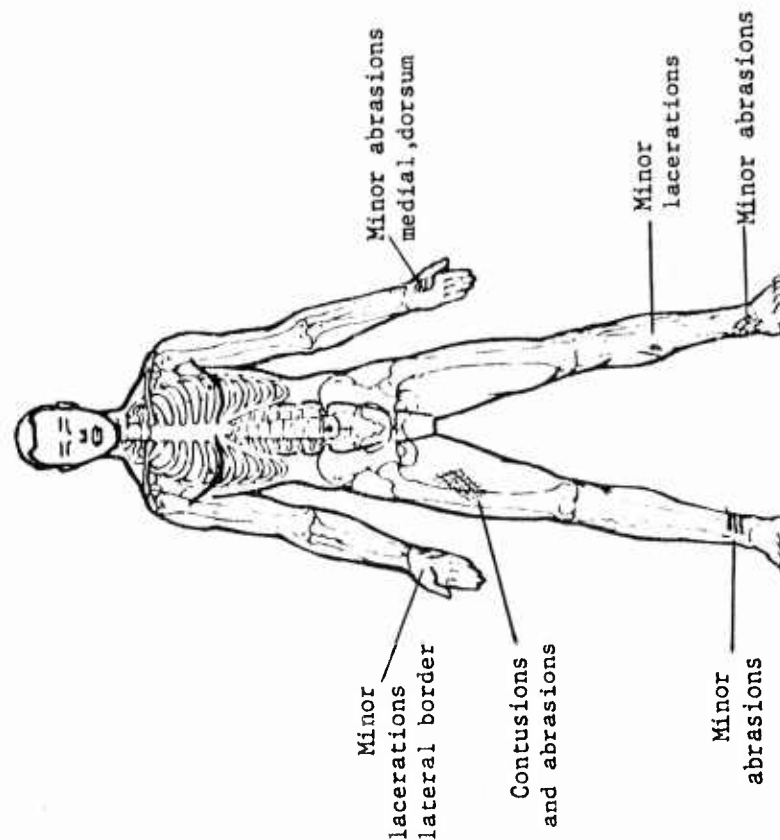
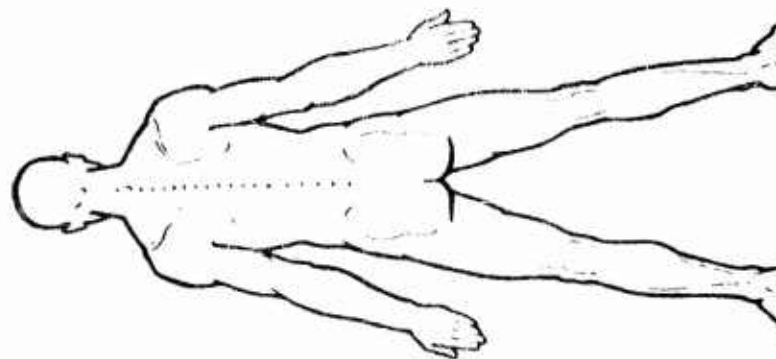
PASSENGER - R-4



HU-1A - FORT BRAGG, NORTH CAROLINA

20 AUGUST 1960

PILOT - RIGHT SEAT

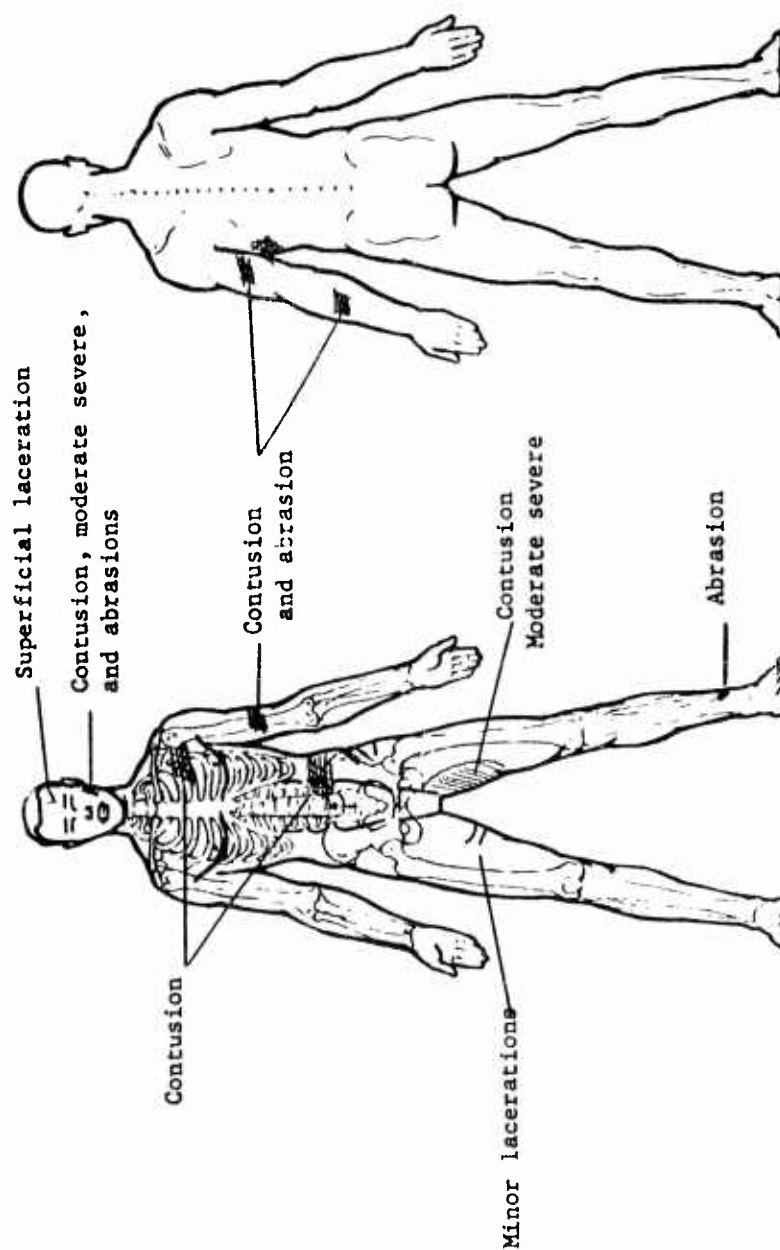


HU-1A - FORT RUCKER, ALABAMA

26 AUGUST 1960

# APPENDIX D

CREW CHIEF - LEFT SEAT



HU-1A - FORT RUCKER, ALABAMA

26 AUGUST 1960

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